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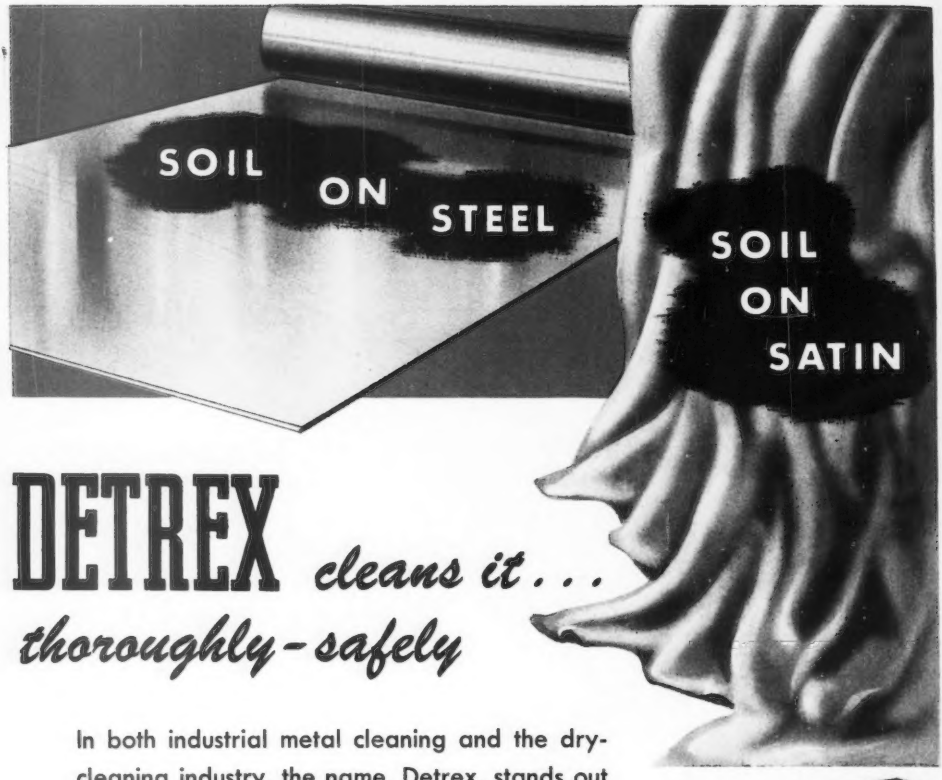
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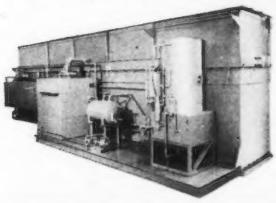
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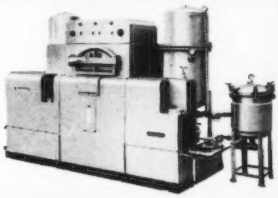
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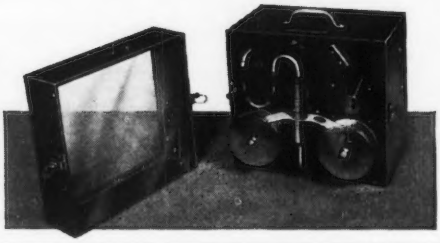


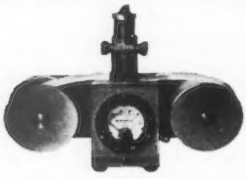
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Nitrogen Dioxide and Ozone Concentrations in Welding Operations

HOMER FAY, Ph.D., and P. H. MOHR, Ph.D., Research Chemists
Tonawanda Research Laboratory, Linde Air Products Company
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A CONSIDERABLE amount of work has been reported over the years concerning concentrations of oxides of nitrogen and/or ozone at various welding operations. While results have not always been comparable, owing to variations in sampling and analytical techniques, findings generally showed that concentrations of these contaminants compared favorably with older suggested threshold limits for normal welding conditions.

With the introduction of a maximum allowable concentration* of five parts per million for nitrogen dioxide, and reduction of the maximum allowable concentration for ozone from 1.0 to 0.1 part per million,[1] it was felt desirable to re-examine certain welding procedures. It was considered particularly important that the welding atmosphere be studied by means of analytical procedures, as accurate and specific as possible, but consistent with the limitations imposed by welding conditions. With this in mind, the literature was searched for information on welding, on the behavior of mixtures of ozone and nitrogen dioxide in low concentrations, and on analytical methods. Certain selected analytical methods were studied further in the laboratory and later were used for measuring ozone and nitrogen dioxide concentrations in the air around welding operations.

*Maximum allowable concentration, or threshold limit value, as given in Ref. 1, refers to the maximum average concentration of the contaminant to which personnel may be exposed for a workday (eight hours) without injury to health. It is subject to change as additional information is obtained. It should not be considered as a hard fast line between safe and unsafe concentrations.

Selection of Analytical Methods

Ozone

AFTER a search of the literature, the method selected for ozone analysis was that of R. G. Smith.[2] This method is based on the stoichiometric oxidation of a basic potassium iodide solution by ozone. The pH of the solution is then adjusted to 3.8 by addition of acetic acid, and two minutes later the iodine formed is determined by measuring the optical density of the solution at a wave length of 352 millimicrons with a spectrophotometer.

The original product of the reaction of ozone and basic iodide is iodate:

$$3\,O_3 + I^- \rightarrow 3\,O_2 + IO_3^- \qquad (1)$$

Upon acidification to pH 3.8, iodine is liberated:

$$IO_3^- + 5\,I^- + 6\,H^+ \rightarrow 3\,I_2 + 3\,H_2O \qquad (2)$$

Reaction (2) is only moderately fast at pH 3.8. From the combined reactions one mole of I_2 is thus generated by each mole of ozone.

INTERFERENCES:

Nitrogen dioxide which occurs in welding atmospheres may interfere with this method in two ways.

1. The nitrogen dioxide may hydrolyze to form nitrous acid and nitric acid. Nitrous acid (or nitrite) reacts slowly with iodide at pH 3.8 to form iodine:

$$2\,HNO_2 + 2\,I^- + 2\,H^+ \rightarrow 2\,NO + I_2 + 2\,H_2O \qquad (3)$$

The result of this reaction is a linear increase in optical density with time after acidification. Basic iodide is used in the Smith method to minimize this interference

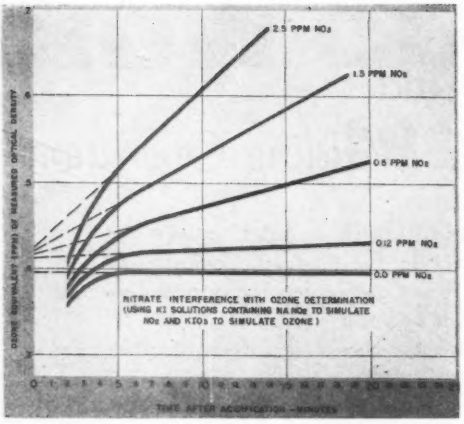


Fig. 1.

of nitrite; however, in the presence of the quantities of nitrogen dioxide that may occur in welding atmospheres, the effect of nitrite may be significant.

The effect of nitrite is shown by the results of tests using aqueous solutions containing potassium iodide, potassium iodate and sodium nitrite to simulate an absorbing solution which has reacted with ozone and nitrogen dioxide. These solutions were acidified to pH 3.8 and the optical density measured as a function of time with a spectrophotometer at 352 millimicrons. Results are shown in Fig. 1 and indicate that increasing nitrite concentrations (calculated as equivalent nitrogen dioxide) give an increasing production of spurious color; that is, color not caused by conversion of iodate to iodine by ozone. Results also show that the release of iodine from iodate in a solution containing no nitrite requires from five to ten minutes. This release may be accelerated by lowering the pH of the solution, but interference by nitrite then becomes more serious owing to faster reaction with the iodide.

To eliminate the interference of nitrites two modifications of the Smith method were used. One, known hereafter as Method I, consisted of correcting for nitrite by extrapolation of the optical density versus time curve to zero time—the time at which nitrite has not yet reacted (Fig. 1). The second modification, known hereafter as Method II, consisted of addition of sulfamic acid to the collecting solution at the time of acidification with acetic acid to eliminate nitrite interference. The use of sulfamic acid was suggested to us privately by B. E. Saltzman of the U. S. Public Health Service, Cincinnati, Ohio. It should be pointed out that experience demonstrated that it was still necessary to maintain the pH of the acidified iodide-iodate solution at about 3.8 even with the use of sulfamic acid if error is to be minimized. This was accomplished by use of a buffered solution of acetic acid and sulfamic acid. Further details on the solutions are given later.

Method I and Method II gave results that were quite similar. Analysis of more than 70 samples of ozone from usual welding atmospheres by both methods showed that the mean variation between the results was about 0.02 part per million of ozone.

2. A second way that nitrogen dioxide may interfere with ozone determination by the Smith method results from the direct reaction of nitrogen dioxide with basic iodide to form iodate. To investigate this reaction, nitrogen dioxide was passed into a basic solution of potassium iodide. A polarographic wave for iodate was found in the basic solution. A similar reaction is described in the literature by Raschig and Prahl[3] and may be written:

$$6\ NO_2 + I^- + 6\ OH^- \rightarrow 6\ NO_2^- + IO_3^- + 3\ H_2O \quad (4)$$

The IO_3^- thus produced cannot be distinguished from the IO_3^- formed by the reaction of ozone.

This second type of interference is not eliminated by either Method I or Method II used for determination of ozone in this investigation. It is probably small with small quantities of nitrogen dioxide, but in view of the low amounts of ozone dealt with in welding, it may cause appreciable error in results. Any foreign ions that absorb radiation at 352 millimicrons will interfere with the determination. No absorption was found for small concentrations of NO_2^-, NO_3^-, IO_3^- and I^-, and therefore these do not interfere with Method I or Method II.

Nitrogen Dioxide

THE METHOD selected for determination of nitrogen dioxide was that developed by B. E. Saltzman.[4] This method is based on the quantitative reaction of a primary aromatic amine with nitrous acid to form a dia-

zonium salt. The diazonium salt reacts further with a coupling reagent to form an azo dye, the color intensity of which may be measured by a spectrophotometer. In this procedure the diazotizing reagent is sulfanilic acid, and the coupling reagent is N-(1-naphthyl) ethylene diamine dihydrochloride. Both reagents are used in the absorbing solution along with acetic acid to adjust the pH.

INTERFERENCES:

Saltzman states that neither nitrate nor low concentrations of ozone interfere with this method. This was confirmed experimentally during this investigation. It was found that ozone interferes only in high concentration by reacting with the reagent to form a different color, or by reacting with the azo dye and bleaching the color. The method was found to be satisfactory in the presence of the quantities of ozone found in welding studies.

CALIBRATION:

The Saltzman method was calibrated with a standard solution of sodium nitrite. Known amounts of the nitrite were reacted with the diazotizing-coupling reagent, and the resulting optical density measured with a Beckman DU Spectrophotometer at 550 millimicrons. The extinction coefficient of the nitrite was thus determined and the nitrite equivalent of an unknown gas sample could be computed from the optical density by Beer's Law.

To convert the equivalent nitrite concentrations to nitrogen dioxide, the stoichiometry of the reactions of nitrogen dioxide and nitrite with Saltzman's reagent was determined. This was accomplished by reacting weighed quantities of nitrogen dioxide with appropriate volumes of the reagent. Optical density was then measured and the relationship of known amounts of nitrogen dioxide to quantities of nitrite needed to produce equivalent color established.

Two sources of nitrogen dioxide were used: (1) thermal decomposition of lead nitrate, and (2) cylinder nitrogen dioxide (stated to be 98% pure). With each source the gas was condensed on phosphorus pentoxide and then distilled into weighed glass ampules. The ampules were sealed and weighed again so that the weight of nitrogen dioxide could be calculated.

The nitrogen dioxide and reagent were brought together by either breaking the ampule under the surface of the reagent, or by breaking the ampule and expanding the gas in an all-glass system in which a known volume of gas could be sealed off and reacted with the reagent.

The mean result of a number of tests indicated that one mole of nitrogen dioxide gas gave a color equivalent to that generated by 0.5 mole of nitrite (NO_2^-). This value corresponds to the expected reaction of nitrogen dioxide with water:

$$2\,NO_2 + H_2O \rightarrow HNO_2 + HNO_3 \qquad (5)$$

This is lower than the 0.72 value reported by Saltzman. Nitrogen dioxide concentrations, therefore, as reported in this study are higher than would have been reported if the Saltzman factor were used.

Studies of Welding Operations

NITROGEN dioxide and ozone concentrations were determined in various types of welding operations. Specifically, nitrogen dioxide was determined in oxy-acetylene, metal-arc, and in argon and carbon dioxide gas-shielded welding; ozone was determined only in argon and carbon dioxide gas-shielded welding. Nitrogen dioxide samples were also collected around an Arcair gouging operation. This is not welding, but was included because it is related to over-all welding procedures. A total of 120 samples were collected and analyzed for nitrogen dioxide and 133 samples were collected and analyzed for ozone. Separate studies were made for each gas and each type of welding. All welding operations studied were manual operations. Appropriate filler metal was used as the operations required.

Location

THE LOCATION for most of the welding tests was a small, one floor building. Its dimensions were: length — 18 feet; width — 11 feet; and height — 10.5 feet. The volume was, therefore, about 2,000 cubic feet. Welding operations were run independently for each gas; no other welding was done in the room at the same time. Windows and doors were tightly closed to eliminate natural airflow, and no other ventilation was supplied during any test. After each test operation the air in the room was changed so that the atmosphere was fresh for each welding operation studied.

As a matter of interest, a few samples for nitrogen dioxide determination were collected in a metal fabricating shop. The findings for these samples are listed separately.

Sampling

NITROGEN DIOXIDE:

Gas samples were collected in the test room at more or less fixed locations. These included: (1) Three positions, hereafter designated side positions, which were two feet vertically and two feet horizontally from the arc in directions away from the welder of 90 degrees, 180 degrees and 270 degrees; (2) In the helmet, except in oxy-acetylene welding in which case the welder wore no helmet; and (3) at six inches from the arc. Samples were collected at each of these locations more or less simultaneously, and several sets of simultaneous samples were collected for each welding setup. It should be noted that the sampling position six inches from the arc was at all times in the fume stream. At the side positions one point was usually closer to the visible fume than the other two. At no time during the study did noticeable fumes pass around the welder's head.

The few samples collected in the metal fabricating shop were taken at locations as time and circumstance allowed.

The samples were all grab samples taken in evacuated spherical bulbs of 1,000-milliliter or 200-milliliter size. The smaller size bulbs were used only when the expected nitrogen dioxide content of the gas was very high.

Each bulb was equipped with two stopcocks, one of which led to a cylindrical funnel of about 25-milliliter capacity through which the reagent could be introduced. The second stopcock was equipped with a spherical joint for connection to a length of ⅛-inch I.D. polyethylene sampling tube. The intake end of the tube had a sintered glass or glass wool filter to remove solids from the gas samples. Calibrated orifices were used to control the rate of sampling which was about two liters per minute.

The bulbs were evacuated to below one millimeter of mercury just prior to a series of tests. Twenty milliliters of Saltzman's reagent were then admitted by slightly cracking the reagent stopcocks and allowing the vacuum to pull in the liquid. The sampling tube was then connected to the other stopcock and the gas sample taken. After sampling, the collected gas was mixed with the reagent by shaking the bulb, and fifteen minutes were allowed to insure complete reaction. The liquid was then drained from the bulbs into screw-cap bottles and kept for a few hours until the optical density could be measured. It should be noted that tests showed that this delay in determining optical density made no difference in readings.

The empty bulbs were always washed thoroughly with distilled water and dried before preparing for new samples.

OZONE:

The same positions and the system of simultaneous samples used for nitrogen dioxide were used in the collection of ozone.

A dynamic system of gas sampling was used in which the air was drawn through about five milliliters of absorbing reagent in a special bubbler by means of a five liter evacuated bulb. The bubblers were blown from 125-milliliter Erlenmeyer flasks. They were partially filled with glass beads so that a large volume of gas could be passed through a small volume of liquid in a short time. Preliminary experiments showed five liters of gas could be drawn through the bubblers in less than two minutes with negligible loss of liquid by evaporation or entrainment. Experiments with two bubblers in series demonstrated that ozone in a concentration of one part per million is completely absorbed in the first bubbler.

The five-liter bulbs were evacuated to one millimeter of mercury just before use. Five milliliters of absorbing reagent were then added to each bubbler and the bulbs and bubblers were connected by polyethylene tubing through 18/9 spherical glass joints. Gas was drawn through the bubbler when the stopcock of the evacuated bulb was opened.

Except for samples collected in the helmet, gas passed only through the short glass entrance tube of the bubbler prior to engaging the absorbing solutions. For collecting gas in the helmet, a three-foot piece of ⅛-inch I.D. polyethylene tubing was attached to the bubbler tube and the intake end was secured in the helmet very close to the

welder's nose. Laboratory experiments demonstrated that there was no significant loss of ozone in passing the gas through either glass or polyethylene tubing. After sampling, each bubbler was drained through the bottom stopcock into a graduated cylinder and washed with several portions of 0.1 M NaOH until a sample volume of 10 milliliters was obtained. Earlier experiments had demonstrated that this washing was sufficient. The samples were stored in screw-cap bottles until they were analyzed. Analysis was usually made soon after sampling, but it was found by experiment that storage for several days did not appreciably affect results.

Reagents

NITROGEN DIOXIDE:

The composition of the absorbing solution used for nitrogen dioxide was as follows:

Sulfanilic acid	2.61×10^{-2} molar
N- (1-naphthyl) ethylene diamine dihydrochloride	7.73×10^{-5} molar
Acetic acid	2.44 molar

The diazotization reaction proceeds rapidly in this solution, but the coupling reaction requires fifteen minutes for completion. The color formed is then stable for several days.

OZONE:

The absorbing solution for both Method I and Method II was a 1% solution of potassium iodide, 0.1 M in sodium hydroxide. The acidifying solutions were: Method I, 3 M acetic acid (180 milliliters of glacial acetic acid per liter); Method II, 3 M acetic acid containing 150 grams of sulfamic acid and 230 grams of sodium acetate per liter. These solutions were chosen so that one part of either acid solution added to five parts of the absorbing solution produced a pH of 3.8 in the final solution.

Analytical Procedure

NITROGEN DIOXIDE:

The gas was collected in evacuated bulbs containing the reagent as described earlier. After shaking the bulb, the solution was allowed to stand at least 15 minutes for complete reaction. The color intensity was then determined by measuring optical density at 550 millimicrons with a Beckman DU spectrophotometer. Nitrogen dioxide concentrations were computed by the formula:

$$NO_2(\text{p.p.m.}) = \frac{RT}{p} \cdot \frac{v}{V} \cdot \frac{E}{ka} \cdot 10^3$$

where R = gas constant = 8.205×10^{-2} (liter atm. degree^{-1} mole^{-1})
T = temperature (degrees Kelvin)
p = pressure in atm.
v = volume of absorbing solution in ml.
V = volume of gas sample in liters
E = optical density at 550 millimicrons, 1 cm. path length
k = extinction coefficient at 550 millimicrons for nitrite in Saltzman's reagent = 4.43×10^4 (liter mole^{-1} cm.$^{-1}$)
a = nitrite equivalent of 1 mole of NO_2 gas = 0.5

OZONE:

For the samples in which the ozone was determined both by Method I and Method II, the absorbing solution, which had been made up to 10 milliliters, was divided into two five milliliter portions. These portions were treated as follows:

Method I: One milliliter of the appropriate acid solution was added to the basic iodide solution and the optical density was measured on a Beckman DU spectrophotometer at 352 millimicrons as a function of time after acidification. The optical density values were plotted vs. time and the resulting straight line was extrapolated to zero time. This extrapolated value of optical density was used in the calculations of ozone concentrations.

Method II: One milliliter of the appropriate acid was added to the basic iodide solution and the optical density at 352 millimicrons was measured after ten minutes.

In view of the agreement between the methods of analysis, findings for samples analyzed by both methods are reported according to the results of Method II only. The remainder of the samples for ozone determination were analyzed by Method I alone.

Concentrations were computed by the formula:

$$O_3(\text{p.p.m.}) = \frac{RT}{p} \cdot \frac{v}{fV} \cdot \frac{E}{k} \cdot 10^3$$

where R = gas constant = 8.205×10^{-2} (liter atm. degree^{-1} mole^{-1})

T = temperature (degrees Kelvin)
p = pressure in atm.
v = volume in ml. of solution whose optical density is measured
V = volume of gas samples in liters
f = fraction of original reagent liquid taken for measurement
E = optical density at 352 millimicrons, 1 cm. path length
k = extinction coefficient at 352 millimicrons for iodine in excess iodide = 2.54 x 10^4 (liter $mole^{-1}$ $cm.^{-1}$)
(Note: This figure must be experimentally measured by each investigator with his own equipment.)

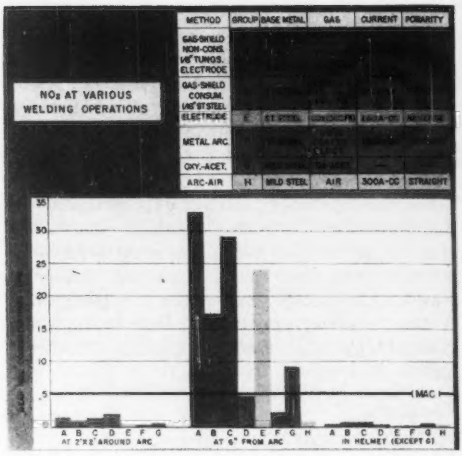


Fig. 2.

Results

NITROGEN DIOXIDE:

Figs. 2, 3 and 4 show the average concentrations of nitrogen dioxide around several types of welding operations under conditions of restricted ventilation which are ordinarily avoided in industrial operations. Generally, the electrodes, currents, gas flows, etc., that were used are those which are commonly encountered in shop practice; however, to explore extreme conditions, gas flows were sometimes reduced to the minimum necessary for a successful weld.

Fig. 2 shows mean nitrogen dioxide concentrations at various sampling positions for a number of welding operations. In general, four to six samples were collected at each of the indicated positions for each of the welding methods investigated. The mean concentrations shown for two feet by two feet around the arc include positions to the right, to the left, and in front of the welder, as previously explained. Invariably one of these points was near the visible fume stream and, as will be shown later, indicated a definitely greater nitrogen dioxide concentration than did the other side positions. Samples taken at six inches from the arc were, practically speaking, always taken in the fume stream.

In Fig. 2 an exception is indicated for the in-helmet samples with oxy-acetylene welding. During this operation the welder wore no helmet and samples were collected close to his nose.

It will be noted that the mean nitrogen dioxide concentrations were considerably higher in the fumes at six inches from the arc than at two feet away, or in the helmet, for all the welding operations. Nitrogen dioxide appears to be formed thermally at the arc and diffuses into the natural air currents around the arc; highest nitrogen dioxide concentrations are, therefore, to be expected in the fume stream. It is interesting to note that the non-consumable, argon-shielded electrode operations apparently produced more nitrogen dioxide than did consumable, argon-shielded electrode welding, in spite of the fact that the current in the latter operation was considerably higher. It seems probable that this was caused, in part at least, by our use of considerably greater gas flow with the consumable electrode (40 cubic feet per hour) than with the non-consumable electrode (9 - 11 cubic feet per hour) in this series of tests. Such a difference is not apparent with consumable electrode welding if the shielding gas is carbon dioxide. Oxy-acetylene welding also produced more nitrogen dioxide than did the consumable electrode with an argon shield, but Arcair gouging with a high current and a carbon electrode showed less. Metal-arc welding at the amperage used and with a coated electrode showed only small quantities of nitrogen dioxide, but past experience has shown that there is considerable increase of nitrogen dioxide with this type of welding as amperage is increased. None of

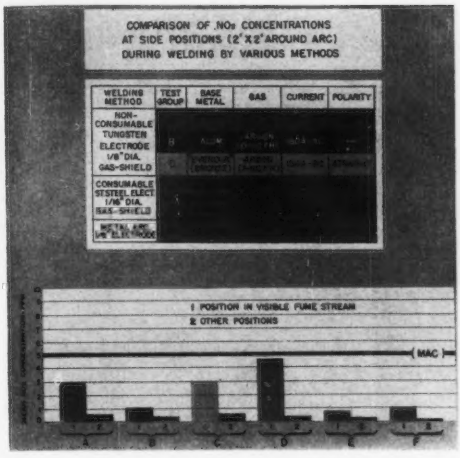


Fig. 3.

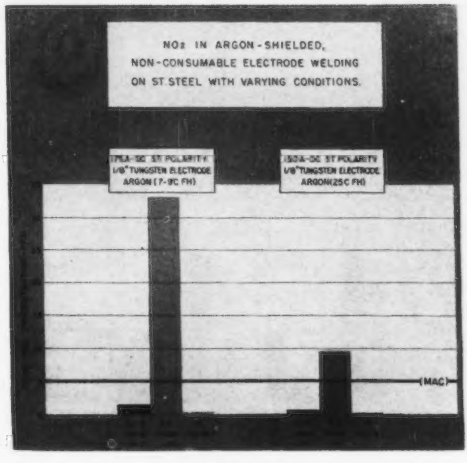


Fig. 4.

the welding methods showed dangerous concentrations of nitrogen dioxide in the welder's helmet or at points of possible occupancy two feet from the operation.

Fig. 3 shows a comparison between mean concentrations of nitrogen dioxide found at two feet from the arc for sampling positions near and away from the fume stream. The results indicate that at this distance the nitrogen dioxide is still considerably higher in the fume stream, and that regardless of the sampling location the suggested maximum allowable concentration is not exceeded. The variation in the order of rank of concentrations in the fume stream from those found at six inches from the arc has no immediately discernible explanation. It is possible that it is related to diffusion currents and gas flows, and also to the presence or absence of ozone which may react with the nitrogen dioxide.

TABLE I.
NO_2 IN A WELDING SHOP

Operation	NO_2 PPM	Remarks	Type of Welding
In 8'x13' closed tank having one 18" manhole at each end	1.6 2.0	General air in tank. No mech. vent.	Metal Arc 350 A-DC-ST polarity ¼" coated steel electrodes
Welding in 8'x13' tank, completely open at one end.	1.7 2.5	Outside helmet in fume stream (2' from arc)	Metal Arc 375 A-DC-ST polarity ¼" coated steel electrodes
General welding shop	0.33 0.40	Random samples	All types in progress

Fig. 4 shows a comparison between mean nitrogen dioxide concentrations at various sampling positions for argon-shielded nonconsumable electrode welding under different conditions of current and gas flow. It will be noted that with a reduction in current and an increase in argon flow the quantity of nitrogen dioxide found at all positions dropped considerably. Inasmuch as the current reduction was not over 20% as compared to an increased argon flow of about 200%, it seems probable that the latter produced the greatest effect on nitrogen dioxide reduction. It should be noted that the higher gas flow shown in this figure is more representative of usual practice than is the lower flow.

Table I is a report of a few samples collected at various locations in a large welding shop. All types of welding were in progress. The building was large, with high ceilings and it had good general ventilation. These samples, collected in midafternoon, upon analysis, showed no great evidence of nitrogen dioxide build-up.

OZONE:

The results of ozone determinations are reported in a manner similar to that used for nitrogen dioxide. The physical setup for sample collection was also the same. Findings are given in Figs. 5, 6, 7 and 8.

The results all reflect maximum ozone concentrations since, as pointed out earlier, any

interference by nitrogen dioxide makes the apparent ozone concentration higher than the true concentration.

In Fig. 5 are shown the comparisons of mean ozone concentrations for positions at two feet by two feet from the arc, at six inches from the arc, and in the helmet. Each finding is the mean of four to six samples. Samples were analyzed by both Method I and Method II; however, in view of the similarity in results only findings of Method II are reported.

For any one type of welding, that is, gas-shielded consumable electrode or gas-shielded non-consumable electrode, a steady state concentration gradient appears to exist between the different sampling locations. For example, with non-consumable electrode welding, concentrations are higher at two feet from the arc than at six inches from the arc, regardless of the metal welded or current used; in-the-helmet concentrations are in between. A steady state concentration gradient is also found for consumable electrode welding with argon or carbon dioxide shield, but in this case the ozone concentration is higher at six inches from the arc than at two feet; again in-the-helmet concentrations are in between.

Comparing the two welding methods, it appears that even at lower current amperage, gas-shielded non-consumable electrode welding tends to produce more ozone at two feet from the arc than does gas-shielded consumable electrode welding. On the other hand, the consumable electrode welding produced more ozone at six inches from the arc for the conditions of the tests. The reason for this difference has not been determined, but it seems likely that it is related to the fact that more fume was produced by the consumable electrode.

With nonconsumable electrode welding, alternating current evidently causes less ozone formation than does direct current at comparable amperages. For procedures involving straight polarity only, as shown by Test Groups A and C, the difference in current amperage probably accounts for most of the variation in the findings.

Fig. 6 shows the comparison of mean ozone concentrations found in samples taken at positions two feet from the arc. Each concentration shown is the average of two to four samples analyzed by Method II.

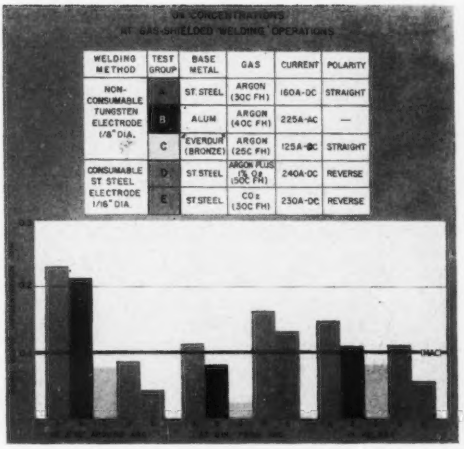


Fig. 5.

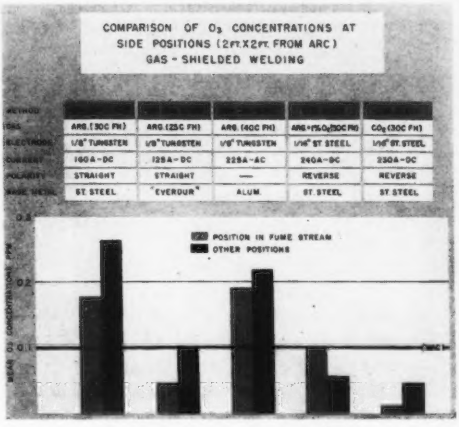


Fig. 6.

Generally, it appears that there is less ozone in the fume stream than at other positions two feet from the arc, or at least there is little variation between the locations. This is in accord with the expected formation of ozone by radiant energy at all points around the arc. The movement of the fume stream does not indicate the direction of ozone flow.

Fig. 7 gives the comparison of mean ozone concentrations (Method II) at positions two feet from the arc for nonconsumable electrode welding with varying amperages of alternating current and constant gas flow. It is evident that reduction in amperage produces reduction in ozone concentrations. It

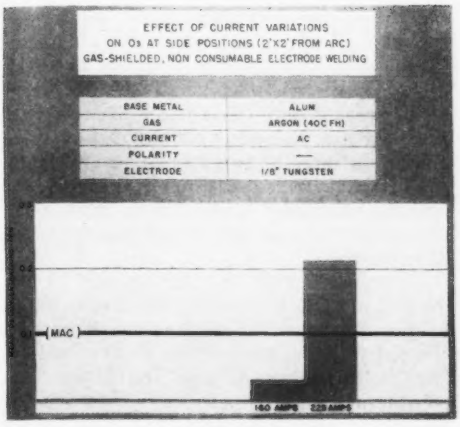


Fig. 7.

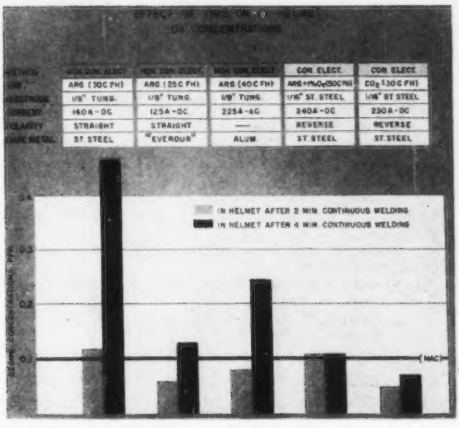


Fig. 8.

seems reasonable to conclude that similar results may be expected with direct current.

It was expected that there might be some build-up in ozone with extended welding time. Fig. 8 is a graph of the findings of in-helmet concentrations at time intervals during welding. Results indicate that build-up may occur at this sampling position, but not excessively if welding time is not consistently greater than average. We found no evidence of build-up in the general room air. Samples were analyzed by Method I.

Discussion

IN VIEW of the findings it appears that the precautions which have been recommended for many years past in connection with welding procedures are still applicable. That is, welding should be done in large open areas with good general ventilation, either natural or mechanically supplied. If it is necessary to use small enclosed spaces, it is advisable to supply local exhaust ventilation.

Nitrogen dioxide is apparently produced in moderate quantities, but it tends to follow the fume stream. For conditions used in this investigation, it did not seem to exist in significant quantities either inside the helmet or at points two feet removed from the arc, except in the visible fume. With only fair general ventilation it should be rapidly diluted to a safe level.

For the gas-shielded welding operations studied, ozone concentrations ranging from 0.01 to 0.7 part per million were found. The average concentration of ozone for all tests was 0.11 $\pm$ 0.05 part per million. The reported findings, however, must be considered as maximum concentrations since it was not possible to completely eliminate interference of nitrogen dioxide from analytical procedures, and ventilating conditions were much poorer than recommended for welding practice. Further, the findings do not reflect expected workday exposures. Extended investigation to determine the operating factor or time of arc operation has shown that shielded-arc welding is an intermittent operation totaling about three to five minutes out of 10 minutes in average practice. Applying this factor to findings of this study, it was concluded that weighted exposure of an operator probably would not exceed 0.1 part per million with reasonably good working conditions. While evidence pointed to a build-up of ozone during continuous arc operation there was nothing found to show that it would continue to exist for extended periods when the arc was discontinued.

The final disposition of the nitrogen dioxide and ozone is not known. Where they are found together they may react with each other. It is also possible that they are extensively affected by air-borne particulate matter formed in welding.

On the basis of possible reaction between nitrogen dioxide and ozone, it seems reasonable to expect more free ozone at six inches from an arc when the quantity of nitrogen

dioxide is low than when it is high. This seems to be reflected by the findings, but not in a clear-cut manner. It is probable that the presence of fume alters the picture, particularly in gas-shielded consumable electrode welding. With an argon shield, increased flow of gas produces a reduction in nitrogen dioxide, possibly owing to increased cooling, exclusion of oxygen, or a combination of these and other effects. Decrease in amperage should produce decrease in both ozone and nitrogen dioxide.

The presence of ozone in the helmet and the comparative absence of nitrogen dioxide is presumably related to the fact that ozone is produced at that point, whereas nitrogen dioxide reaches the helmet only according to the motion and diffusion of the fume stream.

Summary

NITROGEN dioxide concentrations were determined in oxy-acetylene, metal-arc, and several gas-shielded electrode welding operations. Ozone was determined in gas-shielded electrode operations only. Nitrogen dioxide was found to be produced by all operations studied; the quantities varying with welding conditions. It occurred in significant concentration only in the fume at six inches from the arc. In-helmet concentrations were minute.

Ozone was found in all gas-shielded arc procedures investigated and, with consideration for the current amperages used, tended to be greater around nonconsumable electrode operations. Quantities found at radial distances of two feet from the arc were often greater than those found at six inches from the arc. In-helmet concentrations were similar to those at two feet in several tests.

With either gas the application of the long recommended standards of ventilation for welding should provide adequate control of exposure.

Nitrogen dioxide was determined by the method of B. E. Saltzman,[4] which was found to give reproducible results that were considered reliable. Ozone was determined by two modifications of the Smith alkaline-potassium iodide procedure.[2] Both modifications reduced the interferences caused by nitrogen dioxide, but neither completely eliminated them. Therefore, findings were considered to indicate maximum concentrations of ozone, and it was felt questionable if the accuracy of either method was nearly so great as that obtained in determination of nitrogen dioxide.

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Alcohol Studies

YALE UNIVERSITY is offering the fifteenth annual session of the Summer School of Alcohol Studies from July 1 to July 27, 1957. Lectures and seminars will be conducted under the direction of specialists in the fields of the social sciences, medicine and psychiatry, religion, education and public health. Workshops will be a featured part of the course. Inquiries should be directed to the Registrar, Yale Summer School of Alcohol Studies, 52 Hillhouse Ave., New Haven, Connecticut.

Environmental Health Studies Associated with Lead-Bearing Steel Production

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Jones & Laughlin Steel Company, Pittsburgh

IN THE LATTER part of the 1930's, a process was developed and patented for adding lead to steel. This development produced a lead-bearing steel which shows a marked improvement in machinability over that of the same steel without the lead, and permits the full mechanical properties of the base steel to be utilized. A normal lead content of from 0.15 to 0.35%, properly distributed throughout the steel, imparts the free machining properties.

The original manufacturer of leaded steel studied the lead contamination problem[1] throughout the manufacturing process. In addition, a rather detailed medical study was presented which included a large number of personnel who were engaged in this process. Medical findings[2] failed to reveal any evidence of abnormal lead absorption. Although elevated lead air findings were encountered in the manufacturing cycle, exposures were of short duration and intermittent in occurrence which brought down the average daily intake to well within safe limits. Highest exposures were recorded at the steel pouring operation where lead was added to the steel.

With the experience gained in this original process from the standpoint of hazard due to lead, a similar process was undertaken by our Corporation. Careful and detailed planning went into this project with major consideration given to the minimization of the health hazard risk from lead. As a result, a system of portable ventilation was designed and incorporated with a mechanized system of adding lead to steel, eliminating wherever possible the human element.

Operation

IN THE making of leaded steel, the addition of lead is quite critical, as the lead must be dispersed uniformly throughout the steel ingot. Any appreciable segregation or concentration of lead in the steel is cause for rejection. For this reason, quality control plays an important role in the manufacture of the product.

Molten steel is tapped from the open hearth furnace or poured from the Bessemer converter into ladles varying from 175 tons in the former to 27 tons in the latter. The ladle is moved by overhead crane to a position directly over the ingot mold. The molten steel is permitted to flow through an unstoppered nozzle located in the ladle bottom into successive molds, where the metal is allowed to solidify. The molds are stripped of the ingots, which are thereafter reheated and rolled in successive operations to a final shape and size.



Fig. 1.
Operation as seen by the steel pourer who is in the foreground.

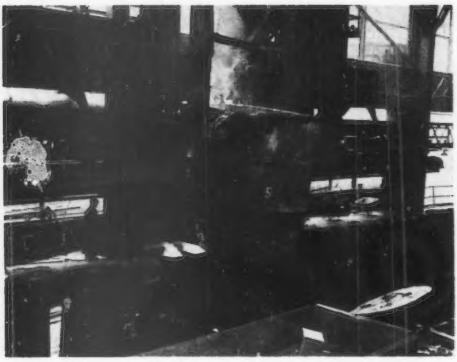


Fig. 2.
Frontal view of open hearth pouring platform.

Lead shot for this operation is selected on a size basis, to have the following sieve analysis: 100% through 20 mesh, 95% on 40 mesh, and 5% on 60 mesh. The lead shot is conveyed by a bucket elevator to a storage hopper and thence by gravity to another hopper located on the crane. The latter holds about 1000 pounds of lead which is roughly the amount needed in an open hearth pour.

During the operation, the lead is delivered from the crane hopper to a proportioner, the output of which feeds the so-called gun. The gun is aimed toward the steel stream; and lead is ejected into the stream (See Fig. 1.). Compressed air is introduced at the discharge of the proportioner, which propels the lead through the piping into the gun and then into the steel stream.

The lead delivery rate is accurately controlled by regulating the speed of the impeller in the proportioner. This is most important, since the mold pouring time varies throughout the operation as the head of metal in the ladle decreases and the nozzle area increases due to heat and erosion. Feed and timing cycles are regulated through electrical circuits.

The entire operation for open hearth and Bessemer pours covers about 35 and seven minutes, respectively. The steel ingot weighs 10,400 pounds and lead is added in the ratio of 6.3 pounds per ton of steel.

Following pouring of the mold, a dolemitic compound is shoveled on the surface of the molten metal. This material serves as a thermal insulator and also suppresses any further volatilization of lead (See Fig. 2.).

Ventilation

THE TEMPERATURE of steel at the time of the pour ranges from 2850 to 2900 degrees Fahrenheit, and the boiling point of lead is 2948 degrees Fahrenheit. Hence, the temperature of the steel is sufficient to cause volatilization of a considerable amount of lead. Approximately 1000 pounds of lead are used over a 35 minute period. The efficiency of the lead addition procedure is about 70%. Thirty percent of the lead used may be lost in two ways: as a fume to the atmosphere, and as accumulations in the bottom and top of the ingot, later to be removed in a cropping operation. It is apparent that an exhaust ventilation system is needed to capture the substantial quantity of lead which may thus be released into the working environment.

The final hood design included a portable plenum whose movement was synchronized with that of the ladle by attachment to the overhead crane. Tracks were installed along the forward edge of the pouring platforms to accommodate the plenum. The plenum, hereafter referred to as the ventilation buggy, has dimensions of 32 inches by 26 inches through its cross-section, with a length of 11 feet. The relative position of mold, ladle, and buggy is shown in Fig. 3.

A slot, ranging from 4½ inches to 8½ inches extends the length of the buggy. Lateral extension adapters, fastened over the slot, bring the face or plane of the exhaust opening some six to eight inches from the leading edge of the mold top. Hence, in practice, air is moved laterally over some four mold tops (mold to be poured, one being poured, and two that have been poured) into the exhaust opening. Greatest air flow is through that section of the hood opening facing the mold being poured. Average velocity through hood opening is about 3500 feet per minute with an air flow rate of approximately 20,000 cubic feet per minute.

An oval shaped header extends the length of the pouring platform with about 20% of the header periphery being open. Two rubberized conveyor belt lips are fastened to this opening making an effective seal. A flared riser from the buggy makes contact with the header through the rubber seals (See Fig. 2.). In operation, the air flows through the buggy into the header at the

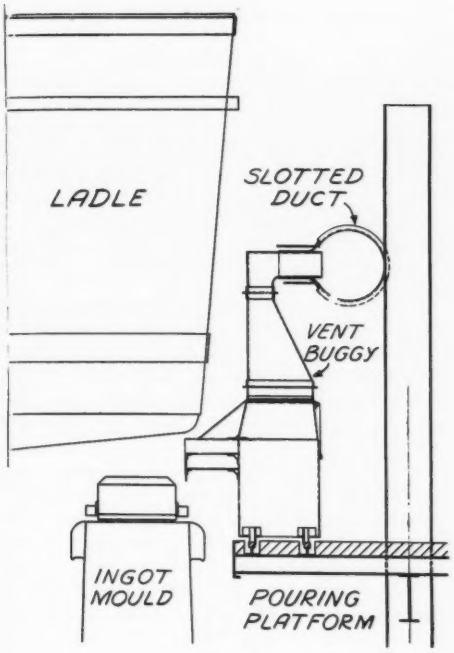


Fig. 3.

point of contact with the rubber lips sealing off the rest of the header. A static pressure of about four inches is maintained in the header.

Each header for two pouring platforms connects into a main, (an electrically operated by-pass damper controls air flow through either of two headers serving open hearth or Bessemer converter pouring platform) thence into filter house, fan and discharge. The filter system consists of a fabric stocking-type unit of about 12,000 sq. ft. filtering area. The exhauster is directly connected to a 100 horsepower synchronous motor. The collected material from bag house is discharged into metal containers, sealed, and disposed.

Other Control Features

IN THE handling of toxic materials, certain measures and practices are basic. These are: good housekeeping, no eating in processing areas, and encouragement of good personal hygiene. A preliminary educational program of instructing men to potential hazards of lead was given prior to the start of this operation. An enclosed area was erected near the pouring platforms which was furnished with a refrigerator, wash facilities, as well as eating facilities. Men were encouraged to wash and eat in this area, rather than eat on the pouring platform as is the usual custom in the steel industry. Personnel engaged in the handling of lead were furnished two lockers, one for street clothes and one for work clothes. Many of the men shower at the end of the shift.

Housekeeping is generally good on the platforms. The lead shot is supplied in cloth bags and stored on pallets in a special area. The bags are brought to the platforms on pallets as needed and lead is fed into the bucket elevator which discharges into a large supply hopper.

At the inception of the leaded steel pouring operation, some of the men requested respirators which were promptly issued. Gradually, the men abandoned the wearing of these respirators as the operation became routinized.

Air Analysis

AIR analyses have been made from time to time during the pouring operation to determine the level of lead contamination. These data have been used exclusively as a measure of control effectiveness, and to check the various factors responsible for affecting the ventilation control. From the onset of this operation, biological and medical findings were used to measure the lead absorption and to detect any early sign of lead intoxication. Less significance was attached to the interpretation of air data as a means of defining the degree of the hazard.

With potential contamination of this type where men are exposed intermittently to lead air concentrations of varying magnitudes, considerable difficulty is encountered when one attempts to interpret air sample data as a measure of severity of exposure. When one considers that different men on one shift may be exposed to varying amounts of lead fumes on successive days for a one-week period, then have no lead exposure for two weeks, the impracticality of estimating lead intake becomes apparent. A far more rational approach to the problem is to use the man as the sampler and integrator of exposure, and to follow his absorption

TABLE I.
LEAD AIR ANALYSIS

Location	Lead-Air, mg/M³ Max.	Min.	Avg.
Pouring Platforms Gen. Atm. Conc. Prior to Installation	0.008	0.001	0.003
Pouring Platforms Gen. Atm. Conc. Before & Following Lead Steel Pouring	0.231	0.001	0.043

through periodic urinary and blood lead analyses.

Base line air determinations for lead were made prior to beginning the production of leaded steel and were found, as shown in Table I, to be within normal general air pollution limits. The air measurements, which are now routinely made before and after the teeming of leaded steel, indicate no appreciable lead contamination, and establish the effectiveness of the control method in use. These findings are shown in Table I.

The system of fume control was tested in several experimental runs before full operations were started. Certain modifications of the buggy evolved following these experimental operations, until the lead air contamination was reduced to levels as shown in Table II, column one. However, as air sampling continued, operational and equipment difficulties were encountered which accounted for considerable variations in air findings. Many of these difficulties occur unpredictably in steel pouring, resulting in increased lead contamination. However, their occurrence is not frequently encountered.

It should be pointed out that steel pouring is a rugged operation, and any appendage used in conjunction with this operation must be equally as sturdy in construction and as simple as possible in design. A mechanism allowing for adjustments of the hood was considered, but was regarded as impractical by operating personnel.

Elevated lead air levels may be encountered under the following conditions: (1) when the stream of molten steel from the ladles cannot be fully shut off; (2) when the stool on which the molds are placed burns through, allowing the steel to escape through the bottom; and (3) when leaks develop at the hot top joint.

TABLE II.
LEAD AIR ANALYSIS

Operation & Location	Lead-Air, mg/M³ No. 1	No. 2
Steel Pourer, B.Z.	0.01, 0.05, 0.31, 0.09	2.59, 0.96
Gun Holder	0.04, 0.10	2.47, 0.74 1.36
Down River End of Buggy (Away From Steel Pourer)	0.13, 0.16 0.05	1.82
Craneman, B.Z.	0.23, 0.07	1.13, 0.98 4.54

In an open hearth teeming operation, six molds are placed on a buggy and about six buggies are aligned on the tracks in front of the pouring platform. When some of the molds are aligned poorly on the buggies, the distance from mold top to hood opening may increase to a point where the fume control is reduced, there being no compensatory mechanism to adjust quantity of air flow.

The levels of lead contamination found at various work sites on the pouring platform under the usual work conditions are shown in Table II, column one. These short-term findings are well below our recognized MAC for lead of 0.15 mg/M³ for continuous exposure. When adverse conditions arise as outlined previously, the lead levels may be of the order as shown in Table II, column two. These extremes in lead contamination found at the employees' breathing area, strongly indicate the necessity of monitoring this operation.

It should be emphasized that the leaded steel operation accounts for a relatively small percentage of the workman's total time. Even under adverse conditions when lead air levels may rise, the employee's weighted average lead intake is below the acceptable lead limit. This is substantiated by periodic medical and laboratory findings.

Medical Program

THE MEDICAL control program for the workmen engaged in the leaded steel operation is recognized as the real test of the continuing safety of the process. All men who might engage in any aspect of the Bessemer and open hearth operations of making leaded steel participated in a careful health inventory, which included a medical history, physical examination, routine urinalysis, serology, chest x-ray, hemoglobin, stippled erythrocyte count, qualita-

TABLE III.
SUMMARY OF URINARY LEAD STUDIES

Time of Exam.	No. Men Studied	Urinary Lead, mg/l Mean	Std. Dev.
Base	138	0.053	0.014
3 Months	89	0.038	0.017
1 Year	33	0.028	0.010

TABLE IV.
SUMMARY OF BLOOD LEAD STUDIES

Time of Exam.	No. Men Studied	Blood Lead, mg/100g Mean	Std. Dev.
Base	180	0.029	0.006
3 Months	88	0.029	0.008
1 Year	22	0.030	0.007

tive coproporphyrin urine determination, and quantitative blood lead and urine lead determinations. All these studies were performed before the operation started and before there was any known lead exposure, and served as a base line for comparison with subsequent findings. These examinations were carried out simultaneously with the lead-in-air studies prior to beginning of leaded steel production. Blood lead levels varied between 0.02 to 0.05 mg/100 grams of whole blood with a mean of 0.029, and urinary lead levels ranged between 0.02 to 0.13 mg/liter with a mean of 0.053. Data are recorded in Tables III and IV. These data compare favorably with the industrial worker of the non-leaded trades.[3,4]

To assure ourselves that no hazardous amount of lead absorption was occurring, the workmen who were exposed to the operation were examined frequently at first, and then as it became apparent that the operation was safe, the period of time for re-examination was gradually lengthened.

As we were able to demonstrate that the workmen were not absorbing any appreciable quantities of lead, the number of laboratory studies was reduced. A qualitative coproporphyrin urine determination and a stippled erythrocyte count are now done with each periodic examination. The time period of exposure of the workmen in the leaded steel operation was the determining factor in frequency of examination. For example, it takes between 30 and 40 minutes in the open hearth to carry out one pouring operation and about seven minutes for the pouring operation in the Bessemer converter. To begin with, the men were examined after approximately two hours ex-

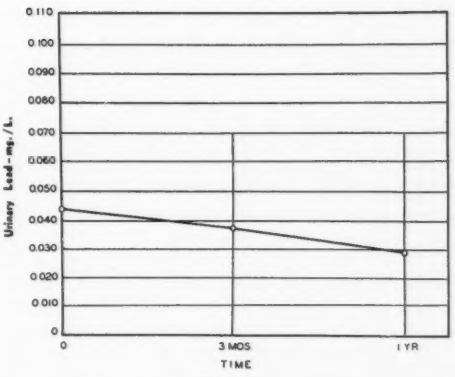


Fig. 4.
Urine lead analysis—33 participants.

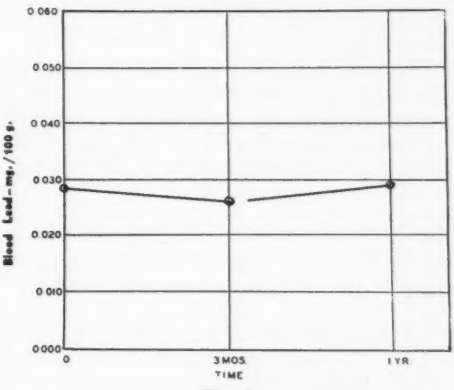


Fig. 5.
Blood lead analysis—22 participants.

posure, this was then doubled to four hours, then to eight hours, and presently potentially exposed workers are re-examined at approximately 18 hours of employment in the operation, or at three to four month intervals.

As the operation progressed, it was found that 33 men carried out most of the operational work in the leaded steel process. Follow-up examinations and laboratory observations were all found to be well within their normal base line data.

In Fig. 4, the curve represents the mean urinary lead values in milligrams per liter for the 33 men. Fig. 5 depicts the mean for 22 of the 33 men in milligrams of lead per 100 grams of whole blood. Thus, no significant absorption of lead could be demon-

strated in the workmen on the leaded steel process after one year of careful observations.

Discussion

IN THE production of lead-bearing steels, some of the lead is volatilized into fumes. The inhalation hazard to the worker is effectively controlled by local exhaust ventilation systems. To insure the effectiveness of such ventilation, observations and studies by industrial hygiene techniques are to be employed. Samples of the lead-in-air at the workmen's breathing zone are gathered by the electrostatic precipitator method. The effectiveness of the exhausting systems is measured, and observations made during various phases of operations. On the basis of such analyses, corrections and improvements can be made.

The usefulness of environmental data in the prediction of the magnitude of workmen exposures or absorption of lead is limited by the marked intermittency of the process, the short-time lead exposures, and the variables in the operation itself. The medical examinations and the laboratory analysis of biological material are of primary importance in assuring the safety of the workman.

Conclusion

AIR ANALYSIS data have established that ventilation control is adequate under normal operating conditions. Operational and/or equipment difficulties occur infrequently which give rise to elevated lead-in-air analyses. Medical findings, supplemented with quantitative biological findings, indicate that there has been no significant lead absorption among the workers after more than one year of exposure experience.

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Summer Program on Noise Reduction

A SPECIAL Summer Program on Noise Reduction, under the direction of Professor LEO L. BERANEK with assistance from the instructing staff of Massachusetts Institute of Technology and distinguished industrial engineers, is being offered at M. I. T. in August, 1957. The program comprises two one-week units. From Monday, August 12 through Friday, August 16, the fundamentals of noise reduction will be taught, and from Monday, August 19 through Friday, August 23, new advances in the science of noise control will be taught. The program is directed toward the man with a noise problem, rather than toward noise experts. In the first week, the behavior of sound waves, instrumentation for noise measurement, fundamentals of hearing, sound in enclosures, acoustical materials, and principles of vibration isolation will be discussed. In the second week, criteria for noise control, ventilation system quieting, quieting of office buildings and homes, design of mufflers, instrumentation for vibration measurement, machine and shop quieting, train and automobile quieting, noise from air jets and jet engines, quieting in the aviation industry, instrumentation for measurement of high intensity noise fields, and case histories will be presented. Students may attend either or both of the one-week sessions. For information, write to the Director of the Summer Session, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

Radiation Exposure of Pediatricians

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EXPOSURE to ionizing radiation has become of increasing interest to those concerned with health protection. Not the least of the sources of such radiation exposure at the present time is the use of radiation by the physician. The higher incidence of leukemia in physicians as compared to the general population attests to the fact that medical usage of radiation presents a real occupational health hazard.[1]

In an effort to learn more about the exposure of physicians to radiation, we decided to study various groups of specialists in office practice. Most studies of exposure have heretofore been confined to hospital practice.[2,3,4] The choice of pediatricians as the first group was arbitrary, but it was influenced by the fact that in the Cincinnati area, most of them have x-ray equipment in their offices. The information we sought was: (1) the extent of use of the x-ray equipment, (2) the magnitude of radiation dose received, and (3) the factors contributing most to excessive or unnecessary exposure.

Our survey activities were confined to Hamilton County, Ohio, and included 55 members of the Cincinnati Academy of Medicine in private practice, who restricted their practice to the care of infants and children.

Forty-five of these pediatricians used x-ray equipment in their practices. Because of shared offices, there were 35 x-ray installations for the group. In only two offices were roentgenograms made, in each case by a technician. None of the physicians used radium or radioisotopes. Our survey activities were, therefore, confined to the fluoroscope, and all but one was surveyed.

DR. ZAVON is now associated with the Kettering Laboratory at the University of Cincinnati.

Procedure

THE SURVEY consisted of four principal parts: (1) time-of-use measurement, (2) comprehensive personnel dosimetry, (3) inspection of equipment, and (4) gross pathology.

1. *Time-of-Use Measurement*: Following an initial telephone contact and visit by the physician member of the team, a time totalizer was installed and left for two weeks. This instrument was designed and built expressly for this study to obtain time-of-use data on fluoroscopes.[5] The principle of operation can be seen by inspecting the schematic diagram in Fig. 1. The low-voltage winding of a transformer is placed in series with the fluoroscope. Current passing through this winding induces a voltage in the high-voltage winding which operates a relay, which in turn operates the elapsed time indicator. The variable transformer is used to adjust the sensitivity of the instrument so that it will discriminate between filament current and total current, and thereby record only the time during which x-rays are actually being generated. The installation is very simple; the time totalizer is plugged into the wall receptacle and the

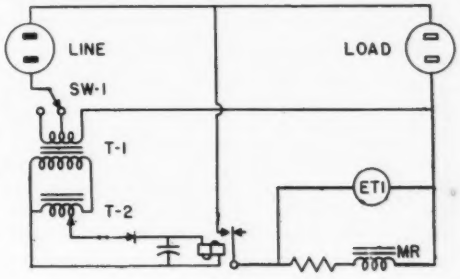


Fig. 1.
Schematic diagram of time totalizer.

fluoroscope is plugged into the receptacle on the time totalizer. The sensitivity is adjusted, and the installation is complete. The instrument was also equipped to count the number of exposures made. The exposure counter was added as a check on the operation of the device and on the presumption that the counts obtained might have some significance. This cord-connected time totalizer obviously could not be used with fluoroscopes which had permanent connections to the power source. Two different time totalizers not requiring direct connection have now been developed, but they were not ready in time to be used in this study.

2. *Comprehensive Personnel Monitoring*: During the first or second week of the time totalizer installation, comprehensive personnel monitoring was performed. Ten extra pockets were sewed on white duck laboratory coats to hold 200 mr pocket chambers (Landsverk). These were located on the shoulders, forearms, left breast pocket, right lapel, lower right front pocket, right and left hems, and back of neck. The ten chambers were used because of anticipated wide point-to-point variation in dose, due to proximity to the source and the use of partially protective aprons. Furthermore, we wished to determine if any specific area was liable to exposure. All pocket chambers had been subjected to a one-week leak test and those leaking more than 5 mr per week were not used. The physician was requested to wear the coat whenever he used the fluoroscope. The protective apron, if worn, was to be worn over the coat. Where more than one physician used the same fluoroscope, each was warned not to leave his coat where it might be exposed to x-ray in his absence. In obtaining this personnel exposure data, we received full cooperation. Personnel monitoring was carried on for one week, long enough to give reasonably valid data for the group as a whole. Physicians whose pocket chambers went off scale in one week were monitored for six to eight weeks with film badges.

3. *Survey of Equipment*: A survey of the equipment was made, consisting of the following: dose rate of the useful beam; dose rate of stray radiation in occupied areas; effectiveness of diaphragms in confining the useful beam; grounding, and condition of protective gloves and aprons.

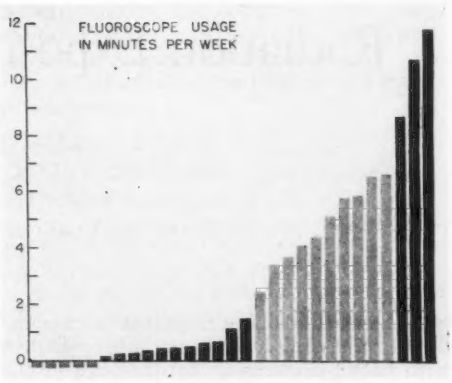


Fig. 2.
Fluoroscope usage in minutes per week.

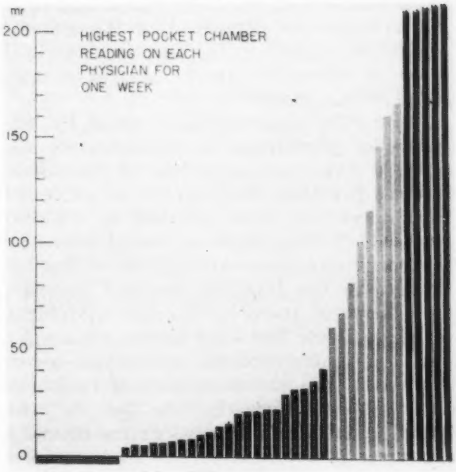


Fig. 3.
Highest pocket chamber reading on each physician for one week.

At the start of the study, dose rates of the useful beam were measured with the condenser-r-meter and also with a 10r Keleket dosimeter. The readings were in substantially good agreement. When the condenser-r-meter became inoperative, the 10r dosimeter alone was used.

The dose rate of stray radiation was measured with a survey meter of the "cutie pie" type, with a Masonite® phantom, in lieu of a patient, to provide the scattered radiation. Spillage of the useful beam around the edges of the screen was detected

by means of a 3 in. x 4 in. fluoroscopic screen mounted on a wand. This miniature screen was obtained as a sample from an x-ray equipment dealer. Effectiveness of grounding was evaluated by checking continuity from equipment to ground with a simple continuity tester.

4. *Gross Pathology*: Whenever possible, the hands of the physician were examined visually for gross evidence of radiation damage.

Results

1. *Time-of-use*: Time-of-use data were obtained on 29 of the 34 fluoroscopes studied. Five units received no use during the two-week test period. Eleven others were used less than 1½ minutes per week. Only three exceeded seven minutes per week, with the highest being used 11.75 minutes per week. The complete data are shown in the bar graph, Fig. 2.

2. *Comprehensive Personnel Monitoring*: The highest pocket chamber reading of each physician is shown in the bar graph in Fig. 3.* Thirty-one of the physicians (70.5%) received maximum readings of less than 50 mr. Thirty-nine (88.6%) received less than 200 mr. Five (11.4%) wore one or two chambers which went off scale, indicating exposures in excess of 200 mr, but not necessarily in excess of the maximum permissible dose. Film badges subsequently issued to these five physicians and worn for six to eight weeks did not exceed 210 mr per week.

The distribution of dose over the body is shown in Table I. This distribution is based on 36 individuals and excludes eight who did not use fluoroscopes during the monitoring period.

As indicated in the table, the forearms and chest generally received the greatest doses. Except when covered by an apron, the chamber worn in the breast pocket was the best single indicator of body exposure.

3. *Fluoroscopic equipment*: There were 14 different makes of fluoroscopes among those studied. Two were portable units with hand fluoroscopes (Fig. 4). About half of the units were postwar models. There was one

TABLE I.
DISTRIBUTION OF WEEKLY DOSE

Point of Attachment	Mean Dose mr	No. of times chamber read highest dose or tied for highest dose
Left Forearm	40.5	9
Breast Pocket	37.6	8
Right Forearm	37.4	8
Right Lapel	24.7	5
Left Shoulder	25.5	3
Right Shoulder	21.1	2
Right Hem of Coat	17.8	3
Lower Right Front Pocket	15.6	3
Left Hem of Coat	12.4	0
Back of Neck	2.9	0

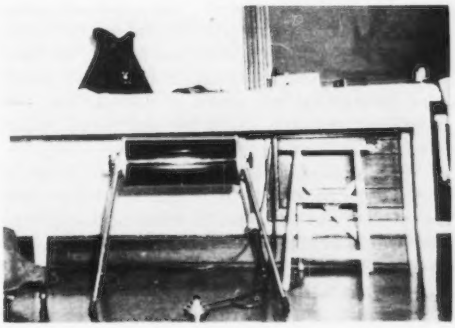


Fig. 4.
Portable x-ray unit with hand fluoroscope.

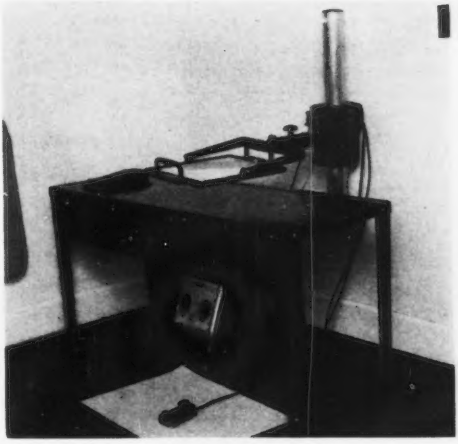


Fig. 5.
Horizontal fluoroscope built especially for pediatric use.

*Pocket chamber readings are reported here as read. They are subject to error due to energy dependence. It is not possible to correct these readings as they were obtained over a wide range of conditions of kilovoltage, filtration, and scatter. Based on comparisons with the Victoreen 0.25r chamber and using the best available energy dependence data, it is estimated that the actual doses are about 20% greater than the readings.

vertical model that was used by a pediatrician who shared an office with an internist. The remainder were horizontal or tilting types, and the tilt models were rarely used in the vertical position. Fig. 5 shows a nontilting horizontal model made especially for pediatricians.

Dose rates measured at the table top with a 10r dosimeter are shown in Fig. 6. Six fluoroscopes exceeded 20 roentgens per minute, sixteen ranged from 10 to 20, and 12 indicated dose rates of less than 10r/minute. The highest reading was 37.5r/minute.

Stray radiation measured at points occupied by the fluoroscopist exceeded 3000 mr/hr (50 mr/min) in 14 cases.

Places where stray radiation was highest were at level of patient (90° scatter), and the space from beneath the table top to the floor (45° scatter from underside of table and leakage from tube housing). The Bucky slot or equivalent, when provided, was also a convenient exit port for scattered radiation.[6]

Nearly half of the fluoroscopes examined were not grounded. Of these, some had been grounded, but the wire had been pulled loose. Several were grounded in part, *e. g.*, the control stand was grounded but not the table. A metal foot-switch was not grounded. This could cause a fatal shock to the physician if the insulation deteriorates. Some apparent grounds were not grounds at all,

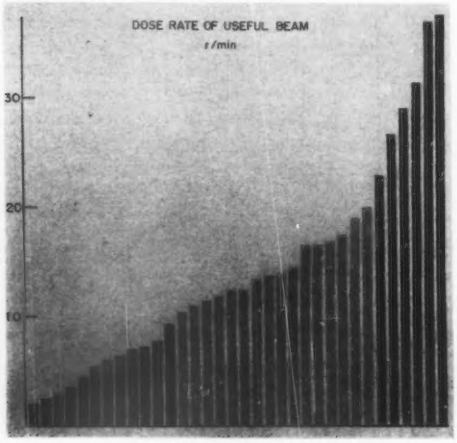


Fig. 6.
Dose rate of useful beam in roentgens per minute, as measured with Keleket 10r dosimeter.

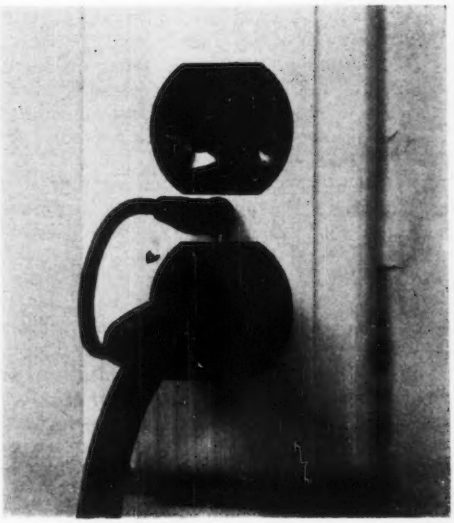


Fig. 7.
Showing one method of grounding.

for example, Fig. 7 shows a power cord "grounded" by a grounding stud on the screw which holds the cover plate to the outlet box. But the box had not been grounded by the electrician at the time of installation and therefore the apparent ground was worse than useless, giving a a false sense of protection. Another less frequent, but potentially severe hazard observed was exposed high voltage conductors.

All but seven of the physicians had both leaded aprons and gloves, but some did not always use them. Seven aprons and two pairs of gloves were in very bad condition, because of improper storage, rather than use.

4. *Gross Pathology*: Five of the men who were examined, revealed some evidence of radiation damage to the skin of hands or feet or both. In some instances it was not readily possible to examine the physician. Pathological changes observed were dry, cracked nails with longitudinal ridging, piling up of keratin, and dry scaly skin on both palmar and dorsal surfaces.

Discussion

OUR FINDINGS indicate that more than half of the equipment surveyed was used less than 1½ minutes per week. This is significant in designing protection for such in-

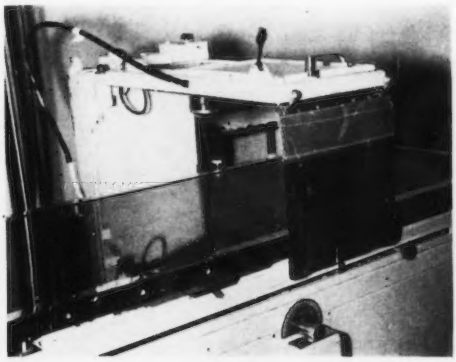


Fig. 8.
Lead curtain as recommended by Handbook 60.



Fig. 9.
Showing an unnecessary opening permitting passage of stray radiation.

stallations, and also in relation to the current drive for registration and regulation of radiation installations.

Most of the exposures were low by comparison with the present maximum permissible limits. The low exposures were, however, not due to intrinsic protection or necessarily to good technique, but rather to the very low work load. For example, one physician used his fluoroscope for 3.63 minutes in one week and received a chamber reading of 81 mr at the lapel. At this rate, his dose could have exceeded 300 mr if he had fluoroscoped more than 13.45 minutes.

Those receiving the highest doses almost always had recognizable and remediable reasons for this exposure. Three of these men wore no protective garments. One of them used a hand fluoroscope. Another had a very high useful beam intensity. One practitioner held the child, and therefore received relatively high dosage on his arms.

National Bureau of Standards Handbook 60, on x-ray protection,[7] required that for routine fluoroscopy, the dose rate measured at the panel or table top shall be less than 10r/minute. For fluoroscoping infants and children the dose rate should be considerably less. This is not only important to the welfare of the patient, but also of the physician. This quantity is controlled by filtration and by using the highest kilovoltage and the lowest milliamperage consistent with a good fluoroscopic image. *NBS Handbook 60* requires filtration equivalent to at least 2½ mm of aluminum. Those fluoroscopes which we were able to check for filtration did not approach this value. More than half of the physicians studied did not dark adapt, and many did not possess the dark red goggles which makes possible the performance of many office tasks during dark adaptation.

Measurement of stray radiation shows that there is much room for improvement in the protection provided in the fluoroscopic equipment, and post war models were not markedly different from prewar models in this respect. *Handbook 60*, recommends a curtain of ¼ mm lead-equivalent hanging between the patient and the fluoroscopist in horizontal fluoroscopy, but none of the

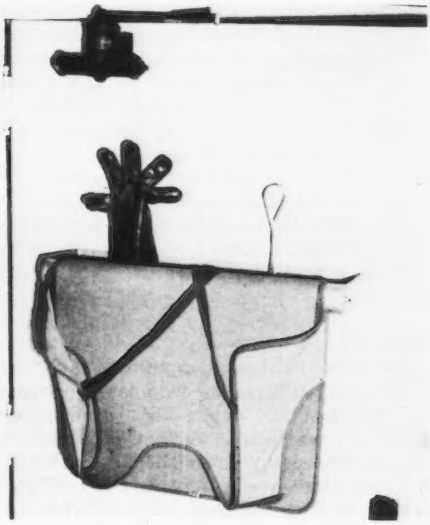


Fig. 10.
Storage rack for apron and gloves.

fluoroscopes tested was so equipped (Fig. 8). Many of the fluoroscopic tables were provided with a Bucky slot, but this was unnecessary, as Bucky diaphragms were not being used (Fig. 9). It would be a simple matter to close these unnecessary openings with a leaded panel. The stray radiation striking the legs and feet of the fluoroscopist consists of scatter from the underside of the table top and leakage from the tube housing or both. The first can be controlled by a cone extending from the tube housing to a position as near the panel as possible. Such a cone is required by *Handbook 60*, but none of the fluoroscopes tested was so equipped. The cone is also useful to limit the angle or sector of the useful beam, as is the adjustable diaphragm, or shutter. *Handbook 60* requires that when the diaphragm is open to its fullest extent, a margin of at least one-quarter inch of unilluminated fluorescent screen is left regardless of screen position. Only six fluoroscopes were found which met this requirement. On several fluoroscopes, the screen and tube moved independently of each other, a very dangerous feature.

Leaded aprons must be stored so that they don't crease, otherwise, they will crack. Leaded gloves should be kept open so that they will dry out between wearings. Fig. 10 shows a convenient and adequate means for storing both gloves and aprons. The protection afforded by an apron depends upon its lead equivalent and also on the area it covers. Figs. 11 and 12 show two apron designs. The apron in Fig. 11 does not need to be worn as low as is shown in the photograph, but we found that they were often worn in this manner.

No follow-up has been made, but we have learned of three physicians who have made extensive modifications in order to increase safety.

Summary

THE WORK habits and equipment of 44 Cincinnati pediatricians who use fluoroscopes in office practice, were studied to determine radiation exposure. Several pediatricians shared fluoroscopes, so the study involved 34 machines, representing 14 different makes. A time totalizer made expressly for this study, obtained time-of-use data on 29 of the 34 fluoroscopes.



Fig. 11.
Protective apron. This type was often worn low, as shown, permitting exposure of upper part of chest.



Fig. 12.
Leaded apron covering all of chest and shoulders.

Sixteen fluoroscopes were used less than 1½ minutes per week. Three exceeded seven minutes per week, with the highest being used 11.75 minutes per week.

A laboratory coat with 10 pocket cham-

bers was given to each physician for a week to be worn during fluoroscopy. The pocket chambers were at various places about the body to determine exposures at these various points.

All chambers worn by 31 physicians recorded less than 50 milliroentgens. Five doctors had one or two chambers that went beyond the 200 milliroentgen chamber scale.

Measurement of useful beam dose rates showed that six fluoroscopes exceeded 20 roentgens per minute. The highest reading was 37.5 roentgens per minute. Sixteen ranged from 10 to 20 roentgens per minute and 12 were less than 10 roentgens per minute.

[ACKNOWLEDGMENT: We wish to thank Dr. Carl Wilzbach, the Cincinnati Board of Health and the Ohio State Health Department for the courtesies extended in the course of this study. We also wish to thank the Pediatricians of the Cincinnati area for their willing cooperation.]

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Audiology

NORTHWESTERN University is offering a six-week course in audiology, June 25 to August 3, 1957, and an eight-week course, June 25 to August 17, 1957. This will be the Sixteenth Summer Session in Audiology at Northwestern. Each year the enrollment increases as more material is offered in the diversified curriculum. There has been outstandingly favorable response to the course in the techniques for hearing testing. This course, including the practicum required for it, is especially designed to meet the needs of those concerned with hearing problems in industry, and are of particular value to nurses, especially those in industrial and community programs, and medical and nonmedical personnel responsible for hearing programs in industry. In addition to the hearing testing session, Northwestern is offering the following courses: Hearing Aids and Residual Hearing; Principles of Clinical Audiology (advanced clinical testing); The Psychology of Deafness; Aphasia and Related Language Disturbances; Anatomy and Physiology of the Hearing Mechanism; Seminar in the Problems of Audiology; Symposium on Speech and Language Problems Related to Neurological Damage; and several courses concerned directly with the educational development of deaf and hard of hearing children and adults. For further information, write RAYMOND CARHART, Professor of Audiology, the School of Speech, Northwestern University, Evanston, Illinois.

Evaluating the Capabilities of Man at Work
—AN EXPERIMENTAL APPROACH

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Graduate School of Public Health, University of Pittsburgh

THE SUBJECT of this paper is a somewhat new field of investigation in which industrial hygienists must have an increasing interest—that of evaluating the physical capabilities of man at work.

During World War II body size measurements proved valuable in solving some rather bizarre problems of cockpit design and layout, escape hatch size, seating utility and comfort, and protective equipment design. In industry, however, these static, linear measurements (for example, the length of a man's arm) may often be of less importance than a knowledge of what the man can do with that arm in various positions. At the outset then, it is necessary to introduce the concept of the functional dimension defined as a human capability related to the performance of a task at some distance and direction from the subject. The difference between static and functional dimensions can be shown by examples. Anterior arm reach is a static dimension; a corresponding functional dimension might be the torque that could be exerted when the arm is extended. Leg length is a static dimension, with a corresponding functional dimension the push that could be exerted on a brake pedal when the leg is straightened.

The questions for consideration, then, are these: Can the magnitude of the force exerted at different distances from the body be evaluated? Can this relationship be explained in terms of the biomechanics of the arm?

To illustrate an approach to answering these questions, the exertion of a vertical downward force was selected for study. This functional dimension was observed to exert what appeared to be an overriding influence on the ease and efficiency of performing such industrial tasks as assembly with overhead power tools, or the operation of a drill press.

A miniature work situation which simulated a job of this general type was set up in the laboratory and is represented schematically in Fig. 1. The object shown as a bicycle handle grip represents the task position. The subject, seated with his back supported by the backrest of the chair, grasped this handle and exerted a maximum vertical force which tended to bend the beam to which it was attached. This action stretched a pair of strain gauges, upset the balance of a Wheatstone bridge and caused an ampli-

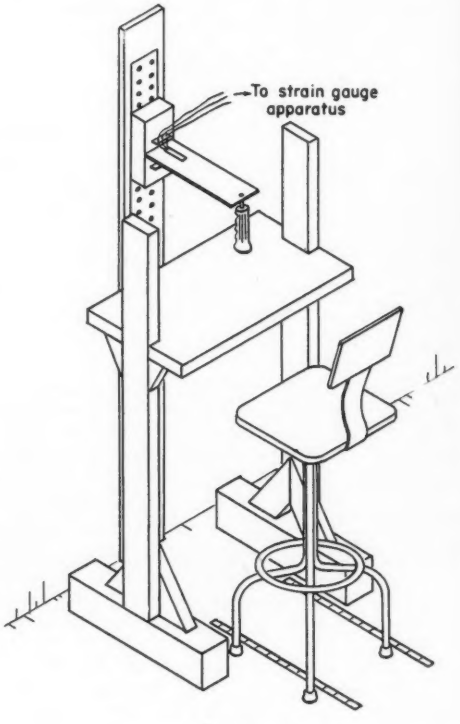


Fig. 1.
Experimental apparatus.

fied current to be recorded which was proportional to the force exerted. Six subjects were utilized in a designed experiment in which the horizontal distance was varied systematically from a minimum to a maximum reach position and the vertical dimension similarly varied in three increments above and three increments below shoulder level.

The three-dimensional curve in Fig .2 describes the dimensional relationship which was found to exist between the exertion of a downward force and the task position. There are some characteristics of this relationship that should be pointed out since they will be discussed later. First, note that at any given vertical dimension the force which can be exerted decreases in an approximately linear fashion as the horizontal distance to the task is increased. The slope of this line becomes smaller, however, as the task position becomes lower relative to the shoulder joint. Actually, at the lowest vertical position, which was nine inches below shoulder level, the subjects could exert no more force close in than they could at maximum arm reach. Secondly, observe that at any particular horizontal dimension, the force decrement with changes in vertical position tends to be curvilinear although this tendency is not as pronounced as the maximum reach is approached.

The systematic nature of this relationship strongly suggests that it can be described on the basis of the mechanics of the muscle and level systems involved. Fig. 3 presents a sketch of these systems. By way of orientation:

O is the pivotal point of the shoulder
X represents the effective lever length
F_v is the downward force which is to be calculated
F is the force perpendicular to the lever length X
α is the shoulder angle
β is the elbow angle
l is a schematic representation of the resultant of all muscles which rotate the arm about the shoulder
b is the distance from the pivotal point to the point of effective insertion of AB
a is a similar distance to a point of effective origin
F_s is the force exerted by the muscle l

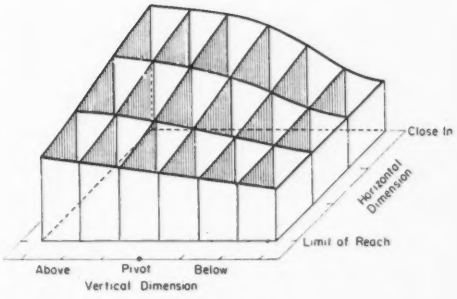
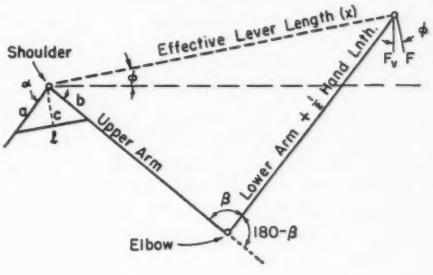


Fig. 2.
Variation in maximum downward force with changes in vertical and horizontal task dimension.



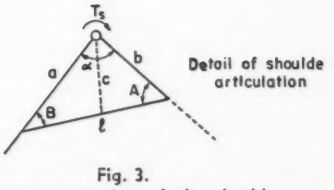


Fig. 3.
Schematic representation of the shoulder-arm lever system.

ϕ is the angle formed by X and a horizontal line drawn at the pivotal point of the shoulder

In a balanced lever system of this kind, it is easy enough to write an expression for the vertical force since F times its perpendicular distance X must equal F_s times its perpendicular distance c. Despite its intriguing simplicity, however, this expression cannot be easily evaluated. Nevertheless, it is possible, by trigonometric maneuvering, to relate F_v to factors in the lever system which can be measured graphically:

$$F_v = K \frac{a}{x} \text{Sin}\left[\text{Cot}^{-1} \left(\frac{\frac{a}{b} - \text{Cos}\alpha}{\text{Sin}\alpha} \right) \right] \text{Cos}\,\phi \; (\text{Sin}\frac{\sigma}{2})^{3/2} \cdot \left(\text{Sin}\frac{180-\beta}{2} \right)^{3/2}$$

This rather imposing equation is an elaboration of the simple lever formula — it contains three parts:

1. The first factor,

$$K \frac{a}{x} \text{Sin}\left[\text{Cot}^{-1} \left(\frac{\frac{a}{b} - \text{Cos}\,\alpha}{\text{Sin}\,\alpha} \right) \right] \text{Cos}\,\phi$$

is an expression for the changing mechanical advantages of the lever system as the task position is changed.

2. The second factor, $\left(\text{Sin}\frac{\alpha}{2} \right)^{3/2}$, is necessary because the force exerted by the muscles is not constant. It has as its basis the fact that the tension which is developed by a muscle is related to the degree of contraction and, hence, the relative length of this muscle.

3. Finally the factor, $\left(\text{Sin}\frac{180-\beta}{2} \right)^{3/2}$, is a recognition of the fact that the exertion of F_v is dependant upon the stability of the elbow joint and is proportional to the degree of contraction of the triceps muscle.

An obvious question is, "How well does this expression predict the ability to exert a downward force?" The answer was obtained in two steps. First, F_v was calculated for a series of task positions in which the shoulder angle, α, remained constant and only the elbow angle, β, varied. These forces were compared with the experimentally determined values and plotted as a function of the changing angle, β. This relationship is shown on the lower portion of Fig. 4. Next in a similar manner the downward force was calculated for a series of task positions in which the elbow angle, β, remained constant and only the shoulder angle, α, varied. These $\frac{\text{actual force}}{\text{calculated force}}$ ratios are plotted as a function of α in the upper portion of this illustration.

If this expression explained the experimental data perfectly, these ratios would have remained constant regardless of the magnitude of the lever angles. It can be seen that in each of the two cases the agreement between the theoretical and the experimental was quite good up to a certain point. As either of the two angles, α or $180-\beta$, became very small the calculated force became too small and the ratio increased. Recalling the nature of the equations, it would seem evident that the error was being introduced by the one factor common to both situations, which is the estimation of the muscle tension as a function of lever angle. Refinements in assumption will be necessary to correct this small discrepancy.

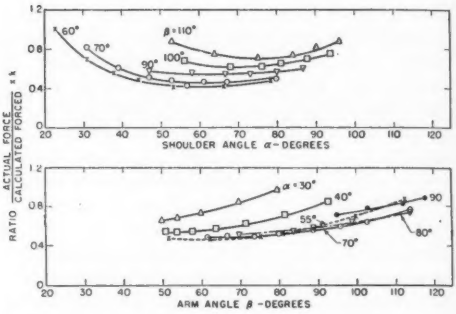


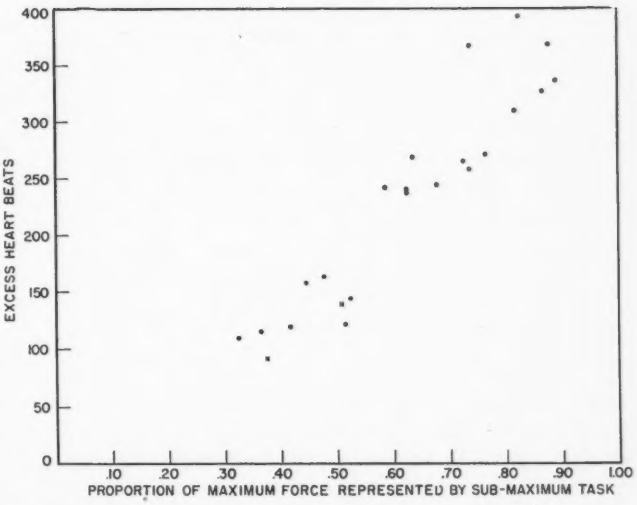
Fig. 4.

$\frac{\text{Actual Force}}{\text{Calculated Force}}$ for varying angles of B and A Subject G.L.

Returning to Fig. 2, the dimensional relationship may now be viewed in the light of the biomechanical expression which has been developed. Note that when the task position is close in, the force decreased at a slower rate above the shoulder pivotal point than below it. This would seem reasonable since in the lowering of the task above the pivotal point, changes in factors governed by the shoulder angle, α, are tending to reduce the calculated force, while changes in cos ϕ and X are tending to increase it. In contrast, as the task is lowered beyond this mid-position, all four factors act in the same direction, *i.e.*, to decrease the calculated force. The net result is a more rapid decrease in force below the pivotal point than above it.

It will be noted further that there is a decided reduction in the slope of the force versus vertical dimension curves as the horizontal dimension is varied from close in

to the limit of reach. The difference in force which can be exerted at a point above the pivotal point and the same distance below it is determined by the shoulder angle since all of the other factors, X, cos ϕ, and 180-β, are equal at these two extreme positions. When the horizontal position is closest in, the difference in shoulder angle between the highest and lowest positions is 74° whereas at the limit of reach the comparable difference is only 42°. This range of shoulder angle variation is consistent with observed variation in slopes.



Association between the index of physiological cost (excess heart beats during sub-maximal task) and the proportion of maximum force represented by sub-maximum task. Subject V.Z.

The experimental procedures employed in this study utilized the criterion of maximum force. Since most industrial tasks can be accomplished with sub-maximal exertions, any general extension of this type of approach to the study of human capabilities must rest upon the acceptance of the hypothesis that maximum force is a predictor of the physiological cost of exerting a submaximal task.

THE FIRST step toward testing this hypothesis was a study requiring three previously trained subjects to perform in 10 minutes, 120 repetitive maximum exertions at some task position. Then, following a complete recovery period, the subject performed a similar number of repetive submaximal exertions at the same position while a common index of the physiological cost, increased heart rate, was being measured. Fig. 5 is a scattergram which shows the relationship between a measure of maximum force and a measure of physiological strain for each of 25 dimensionally distinct task positions. The constant sub-maximum task for this subject was 30 pounds. In those positions where 30 pounds represented a high percentage of his maximum effort, the index of physiological cost rose proportionately. Conversely in dimensionally advantageous positions where he could exert several times 30 pounds, the relative strain of performing this sub-maximal task was low. To the extent that increased heart rate is, in fact, a measure of physiological strain during exercise, the high correlation (0.90) between these two factors tends to substantiate the original hypothesis that maximum force can be used as an estimator of the relative strain on the body during the exertion of a submaximal task. It is evident, however, that this hypothesis needs further testing, using other force exertions and other measures of physiological strain, *e.g.*, oxygen consumption, or muscle potential.

Certainly, the desire to systematize this area of human knowledge is reason enough to undertake a study of this kind. Nevertheless, it is apropos to ask the question, "Does this approach have any practical application?" To this question the answer would be yes. Design engineers are asking with increasing frequency for specific data on human capabilities. What are the optimum load limits for lifting? For carrying? What is the optimum assembly line height for manipulative tasks? How much pull can be exerted on a lever? These are a few of the specific inquiries that have crossed the author's desk during the past few months. What the design engineer really needs is

systematic data which describe the distribution of these characteristics in the industrial population and these data are not available at this time. It is felt that an understanding of the mechanism of force-exertion as well as the underlying force-distance relationships are basic pre-requisites which give meaning to the accumulation of these statistics. After establishing this basic understanding, a relatively few force measurements can be made on a large number of individuals in an industrial population and thereby arrive at a practical knowledge of the capabilities of man at work.

Hazard of Atomic Radiation

THE ATOMIC ENERGY Committee of the International Association of Industrial Accident Boards and Commissions recommended to state workmen's compensation officials at their recent convention at Charleston, South Carolina, a seven-point program to protect workers in atomic industries where there is a hazard of atomic radiation, as follows: (1) there should be given full benefits coverage of occupational diseases; (2) there should be no limit placed on the medical care workers may require either for length of time or cost; (3) there should be studies to determine the advisability of supervised specialized medical care for injured workers; (4) studies also should be made to determine the extension of second-injury laws for affected workers in order to facilitate their re-employment; (5) methods of apportioning liability in cases where workers may have been exposed to radiation in more than one plant will have to be devised; (6) inspection of plants where atomic work is performed should be authorized in order to determine the type and quantity of radiation present; (7) workmen's compensation claims ascribed to atomic radiation should be carefully examined in order to insure that real injuries are properly covered and that imagined or tenuously related injuries are dealt with in a reasonable balance. The Committee pointed out that radiation effects are often difficult to distinguish from other medical conditions, and the question of nuclear neurosis and fear of exposure will undoubtedly be a factor at times. The Committee concluded that while diseases caused by exposure to ionizing radiation will undoubtedly add to work loads of workmen's compensation boards and commissions, it is felt that they will present no insurmountable problems, and that the present recommendations will, if immediately put into effect, give adequate protection to the injured worker.

Collection Efficiency

OF FILTER MEDIA IN THE PARTICLE SIZE RANGE OF 0.005 TO 0.1 MICRON

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CHEMICALLY toxic and radioactive particles and gases may of their very essence emanate from mechanical, chemical, and reactor operations in an atomic energy laboratory. At the Knolls Atomic Power Laboratory, an air cleaning and air sampling program[1] was initiated to provide adequate cleaning of the laboratory air and the air discharged to the environs. Particles emanating from laboratory operations are collected in a variety of air cleaning equipment such as electrostatic and cyclone precipitators, caustic scrubbers, and Dustop and high efficiency filter units. A total of 475,000 cfm of laboratory air is cleaned prior to discharge to the environs. High efficiency air filter units (predominantly CWS-6) clean 80% of the filtered air discharged to the environs. To ensure adequate control of air-borne material and the proper operation of air cleaning equipment, 20,000 air samples are taken yearly and analyzed for their chemically toxic and radioactivity content.

Whatman-40 and Hollingsworth and Vose-70 filter papers are used to collect chemically toxic (beryllium) and radioactive particulate material, respectively, in the Laboratory and the environs. Cascade impactors, electrostatic and thermal precipitators, and Millipore Filters have been used to determine the particle size distribution of materials emanating from operations in the metallurgy, chemistry, and physics laboratories at KAPL. These particle size distributions have included analyses of the particles under a light and an electron microscope.[2] Autoradiographic studies have been conducted using a stripping film technique[2] to evaluate the size distribution of radioactive particles in a heterogenous mixture of radioactive and nonradioactive particles.

An evaluation of the effectiveness of an air cleaning program requires not only a knowledge of the particle size distribution but also the efficiency of the filter media used to collect these particles. To provide an adequate evaluation, one must know the collection efficiencies of the filter media primarily as a function of the particle size, particle velocity in the air stream, and the type of particles used. In an earlier report by Fitzgerald and Detwiler,[3] collection efficiencies were determined for the H-70, W-40, W-41, CC-6, MSA-1106-B, and AEC-1 filter media in the particle size range of 0.1 to 2.1 microns at face velocities of 0.5 to 150 cm/sec using a duraluminum aerosol. This study in itself was not adequate for a complete evaluation of the filter media. A complete evaluation of a filter medium requires a knowledge of the collection efficiency in the size range of 0.005 to 0.1 micron for the following reasons: (1) The majority of the particles in the air upon which radioactive material may be deposited are in this size range.[4] (2) The average particle size emanating from the KAPL separations process operation was 0.05 micron.[1] (3) The maximum penetration of particles, theoretically, occurs in this particle size range when the particle velocity is greater than 1 cm/sec.[5] (4) There is no doubt that particles in this size range will be retained with relatively high efficiency in the aveolar from Brownian movement in the respiratory system.[6]

In this report the following experimental

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results will be discussed: (1) The collection efficiencies of air sampling (W-40, W-41, and H-70) and air cleaning (CC-6, AEC-1, and MSA-1106-B) filter media in the particle size range of 0.005 to 0.1 micron. (2) The theoretical and experimental optimum particle sizes for penetration through the filter media. (3) A comparison of the efficiencies obtained using atmospheric dust, solid duraluminum, and liquid $KMnO_4$ aerosols.

Parameters Affecting Filter Efficiency

THEORETICALLY, aerosols are collected in fiber filter media by several methods: inertia, interception, electrostatic forces, settling, and diffusion. These factors have been discussed in detail in many reports.[7] For a given fiber radius or standardized filter medium, the filter efficiency is predominantly a function of the particle size and the velocity of the particle in the air stream for a specific aerosol. In some instances, the electrical charge of the fiber and the aerosol may have a significant effect on the collection efficiency. The collection efficiency of a filter medium varies with particle size and face velocity in the manner presented in Table I.

TABLE I.
VARIATION OF COLLECTION EFFICIENCY WITH PARTICLE SIZE AND FACE VELOCITY

Collection Efficiency Parameters	Relationship of Particle Size, Dp, and Face Velocity, v, with Collection Efficiency, E
Inertial Impaction	$E \sim v\, D_p^2$
Direct Interception	$E \sim D_p$
Electrical Attraction	
by Charges	$E \sim (v\, D_p)^{-1}$
by Induction	$E \sim v^{-1}\, D_p^2$
Diffusion	$E \sim (v\, D_p)^{-1}$
Gravitational	$E \sim v^{-1}\, D_p^2$

For large particle sizes and high particle velocities, the inertial impaction parameter is an important factor in determining the total efficiency of the filter medium. For small particle sizes and low particle velocities, the diffusion parameter becomes an important factor in determining the total efficiency in the filter unit for the collection of the particles. Collection by direct interception is independent of particle velocity and depends fundamentally on the ratio of the

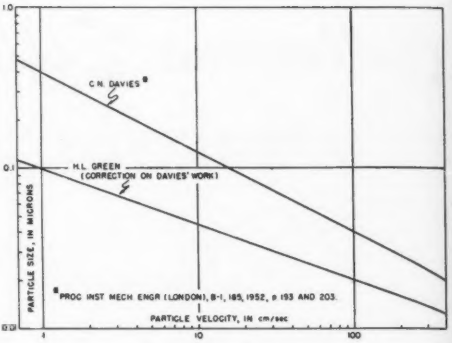


Fig. 1.
Theoretical optimum particle size for penetration through filter media as a function of particle velocity.

particle size to the filter fiber size. Collection by gravity is important when the particle size is large and the particle velocity is small.

Several theories based on these relationships have indicated that each filter medium will yield a point of maximum penetration for a certain particle size at a given face velocity. This theory of maximum penetration evolves from the fact that for a given particle velocity, fiber size (or filter media), and test aerosol, the efficiency of collection by the diffusion mechanism increases with a decrease in particle size, whereas the efficiency for collection by inertial impaction and direct interception decreases with a reduction in particle size. Perhaps the most recent and complete theory has been promulgated by C. N. Davies. In his theory, the optimum particle size, D_p in cm for a maximum penetration through a given filter medium at a specified velocity of v, cm/sec may be approximated in the equation,

$$D_p^2\, v = 4 \times 10^{-9.4}$$

In a review of Davies' theory, H. L. Green pointed out that, using Davies' final equation, the optimum penetration sizes did not occur at the above relationship. The optimum penetration sizes using the equation and the corrected values of Green are given in Fig. 1.

Davies' theory did not consider the gravitational and electrostatic parameters in the determination of the optimum penetration size. In general, the contribution of these parameters in the total collection of parti-

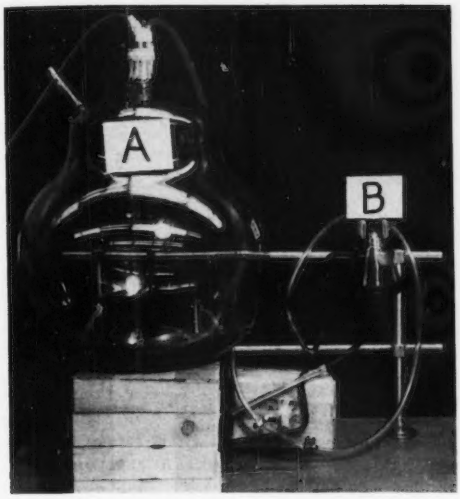


Fig. 2.
Modified $KMnO_4$ aerosol generator.

cles is negligible for the particle sizes and velocities considered. However, the electrostatic effects of some aerosols and filter media may be sufficient to alter substantially the optimum penetration sizes as stated by Davies and Green. In the final analysis, the experimental determination of the optimum penetration size is of greatest significance at this time until more reliable assumptions can be made with respect to theoretical considerations

Experimental Procedure

TEST AEROSOL: In previous studies,[3] duraluminum was used as the test aerosol for determining filter efficiencies in the particle size range greater than 0.1 micron in diameter. The duraluminum aerosol concentration was too low, however, to permit the production of satisfactory electron micrographs for studies in the particle size range of 0.005 to 0.1 micron in diameter. General atmospheric dust was found sufficiently abundant to use as the test aerosol for some of the less efficient filters. The general atmospheric dust concentration in the particle size range of 0.1 to 2.1 microns was approximately one order of magnitude greater than the duraluminum aerosol concentration but was too low for satisfactory electron micrographs in the air cleaner filter efficiency studies in the lower particle size range.

An effort was then made to produce a highly concentrated and suitable aerosol with respect to particle density, detection under the light microscope, physical state, and particle shape. Lauterbach's improved aerosol generator[11] was modified by increasing the size of his aerosol generation chamber to 13 inches in diameter. With this modification, and with the use of a saturated solution of $KMnO_4$, the aerosol concentration was approximately three orders of magnitude greater than when duraluminum was used. Suitable electron micrographs for the filter efficiency studies in the submicron size range were obtained with the $KMnO_4$ aerosol.

The modified $KMnO_4$ aerosol generator is shown in Fig. 2. The letter "A" designates the aspirator and aerosol production chamber. The $KMnO_4$ reservoir is located at "B". The operating principles of this aspirator-type aerosol generator are described in detail by Lauterbach, et al, in UR-377.[11] With a saturated $KMnO_4$ solution, the generator produced 1.1 x 10^9 particles/ft^3, as determined with a light microscope. The particle size distribution was characterized by a geometric mean size of 0.3 micron and a geometric standard deviation of 1.9, based on light microscope particle size measurements.

Standard Filter Sample Collection

THE aerosol was released into the test equipment illustrated at "A" in Fig. 3.

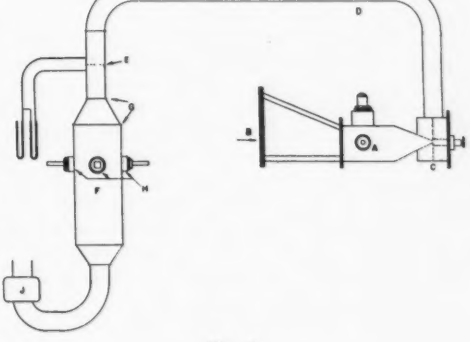


Fig. 3.
Schematic diagram of test unit.

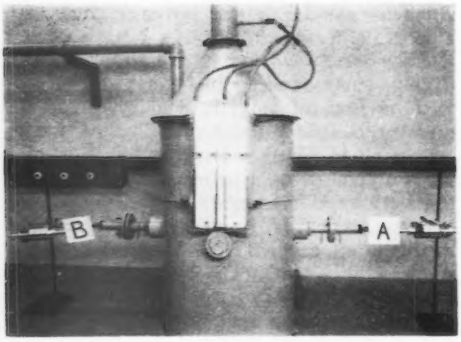


Fig. 4.
Aerosol chamber.

The particles larger than approximately three microns in diameter were collected on the impaction plate at "C", and the particles less than three microns passed into chamber "F". The details of this system were reported in KAPL-1088[12] and the American Industrial Hygiene Association Quarterly.[3]

Equal quantities of the test aerosol were taken isokinetically from the aerosol chamber at sampling ports, "H". The fractions of the test aerosol taken at the sampling ports, "H", were shown experimentally to be equal within the statistical limits of the procedure.

Referring to Fig. 4, the filter under test was held between flanges at the right of "B". The desired face velocity for each filter efficiency test was obtained by the insertion of retainer rings between the test filter flanges. The retainer rings had apertures which varied in diameter (from 0.46 to 6.52 cm) depending on the desired face velocity.

In these experiments, the size of the apertures was varied while the flow rate was held constant. The aerosol sample drawn into the standard filter (Type HA, Millipore Filter) at the right of "A" was equal to the aerosol sample exposed to the test filter. The standard filter to the left of "B" collected the aerosol that passed through the test filter. A comparison of the aerosol collected on the two standard filters permitted a determination of the particle collection efficiency of the filter under test.

SAMPLE ANALYSES: The filter efficiency evaluations were accomplished in two phases. In the first phase, the particles deposited on the standard filter papers were analyzed under the light microscope. This phase involved the collection efficiency determinations of the filter media in the particle size range of 0.1 to 2.1 microns. In the second phase of these filter efficiency studies, the particles in the size range of 0.005 to 1.0 micron deposited on the standard filter papers were analyzed under an electron microscope.

In the light microscope phase of the evaluation, the Millipore Filter is impregnated with microscope immersion oil, which renders the filter transparent. A cover glass is placed over the sample and a standard size count is made. A comparison of the upstream and downstream size counts, corrected for scanning area, then yields the particle collection efficiency of the test filter for particles in the light microscope size range.

In the electron microscope phase of the efficiency evaluation, the Millipore Filter was treated for a size analysis by a silica replication[13] technique.

In the silica replication method the silica film is deposited on the filter by the rapid evaporation in a 0.1-micron vacuum of approximately 1.3 mg of silicon dioxide or silicon monoxide from a coil tungsten filament. The filter is placed 10 cm from the filament and normal to it. The evaporation must be done rather rapidly to avoid damaging the filter by the heat from the filament. Small pieces of the coated filter are then placed on microscope specimen screens, with the silica film in contact with the screen. The



Fig. 5.
Millipore filter unexposed—control filter. Magnification—15,000X.

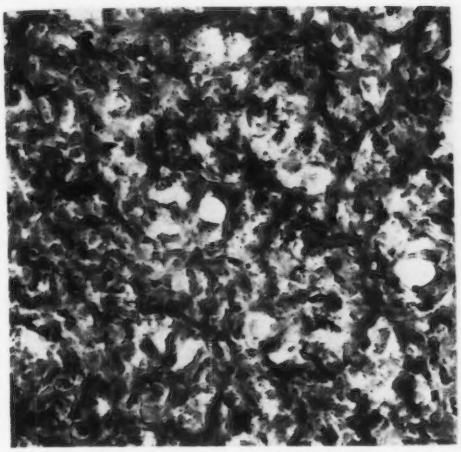


Fig. 6.
Millipore filter. Sample from downstream side of W-40 test filter. Magnification—20,000X. Method of analysis—silica replication.

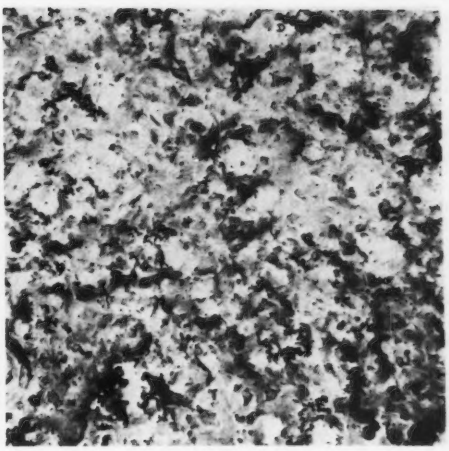


Fig. 7.
Millipore filter. Sample from upstream side of W-40 test filter. Magnification—20,000X. Method of analysis—silica replication.

microscope specimen screen is placed on a 100-mesh screen forming a low table in a depression of a spot plate. Acetone is placed under the table from a capillary pipette until the level of the liquid reaches the top of the table but does not cover the specimen screen holding the sample. Capillary action carries the acetone up to the filter. The level of acetone is maintained until the filter is dissolved.

Electron micrographs are made from the silica replicas after selecting fields representative of the particle size distribution and concentration. Size counts are made from the electron micrographs. The data are analyzed in the same manner as the light microscope data were treated to establish the particle collection efficiencies.

It was necessary to determine the particulate background on unexposed Millipore Filter papers prior to determining the significance of submicroscopic particles shown on the electron micrographs of Millipore Filters exposed to the atmosphere. An electron micrograph of an unexposed or control Millipore Filter is shown in Fig. 5. The surface of the filter paper is shown in replica form with a magnification of 15,000.

An electron micrograph of a Millipore Filter paper exposed to atmospheric test dust is shown in Fig. 6. The magnification is 20,000 and particles down to 0.005 micron are readily discernible even with the obstructing background. Some of this back-

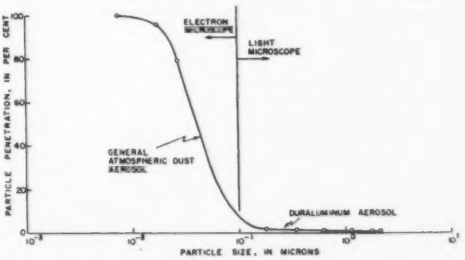


Fig. 8.
Filter efficiency Whatman-40 (40 cm/sec).

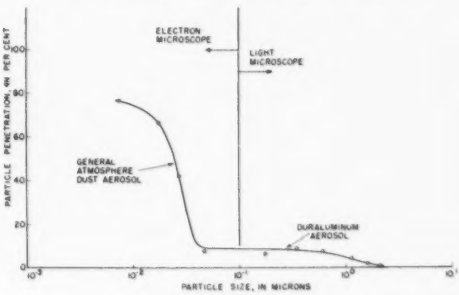


Fig. 9.
Filter efficiency Whatman-41 (10 cm/sec).

ground, however, can be eliminated, as shown in Fig. 7. There appears to be some variation in the surface structure of the Millipore Filters which permits the reduction of the obstructing background, rather than a variation in the technique applied in the preparation of the electron micrograph.

Experimental Results

AIR SAMPLING FILTER MEDIA: The collection efficiencies of the Whatman-40 and -41 filter papers decreased with particle size for particle velocities of 40 and 10 cm/sec, respectively, as shown in Figs. 8 and 9. In these initial studies, duraluminum solid particles were used as the test aerosol in the light microscope particle size range. In the initial phases of this study it was not possible to produce sufficient quantities of the duraluminum aerosol in the lower particle size range. It was, therefore, necessary to use atmospheric dust which provided a larger number of the smaller particles for the study of the relatively low-efficiency filter papers. The particle velocity chosen in these preliminary studies was one at which

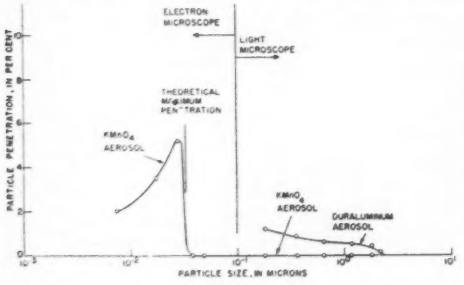


Fig. 10.
Filter efficiency Whatman-40 (150 cm/sec).

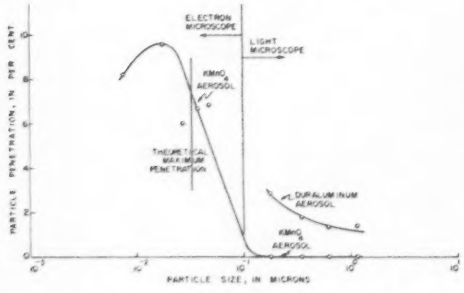


Fig. 11.
Filter efficiency Whatman-41 (150 cm/sec).

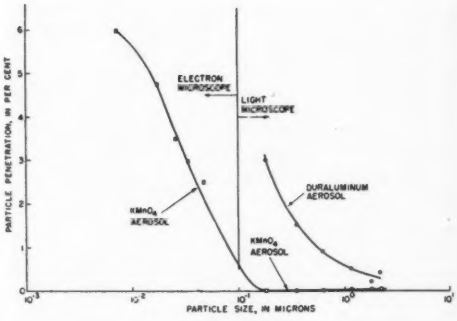


Fig. 12.
Filter efficiency, Hollingsworth and Vose H-70 (10 cm/sec).

the collection efficiency was high in the light microscope particle size range. This choice was made to provide a maximum range in which the collection efficiency could vary as a function of particle size in the electron microscope range. Although a point of maximum penetration as previously defined was not detected in either of these initial studies, the shape of the curves indicated the possible existence of the point at the lowest detectable particle size.

The modified liquid $KMnO_4$ aerosol generator provided sufficient quantities of the aerosol to determine the collection efficiency of Whatman-40 and -41 filter papers at a velocity of 150 cm/sec. This velocity was chosen to approximate the velocity used in the new Health Physics beryllium air samplers. As indicated in Figs. 10 and 11, an optimum size for penetration through the filter papers was detected in the particle size range of 0.01 to 0.04 micron. Both of these points of maximum penetration are in good agreement with the theory of Davies and Green.

The data also indicate that the Whatman-40 and -41 filter papers are greater than 90% efficient in the collection of $KMnO_4$ aerosol over the entire particle size range. As illustrated in Figs. 10 and 11, the Whatman filter papers were more efficient in the collection of liquid $KMnO_4$ particles than for solid duraluminum particles in the light microscope particle size range. The most recent data obtained by the analysis of these filter papers indicate that the collection efficiency at 150 cm/sec is greater for the solid duraluminum aerosols than for the

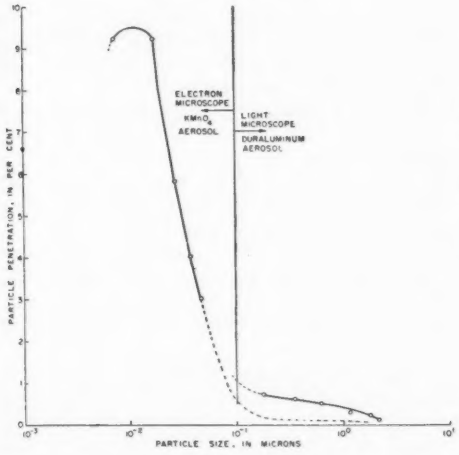


Fig. 13.
Filter efficiency, AEC-1 filter paper (2 cm/sec face velocity).

$KMnO_4$ aerosols in the 0.005 to 0.1 micron particle size range.

In a preliminary study using atmospheric dust, the efficiency of H-70 filter papers for the collection of particle sizes from 0.005 to 0.1 micron at a velocity of 80 cm/sec was very high. A determination of a point of maximum penetration was not possible in this study.

In subsequent collection efficiency determinations of the H-70 filter papers, a particle velocity of 10 cm/sec was chosen using the $KMnO_4$ test aerosol. The collection efficiencies using solid duraluminum particles were relatively low at this velocity in the light microscope particle size range. Since the H-70 filter paper has relatively high efficiency for the collection of particulate material, the velocity corresponding to the point of minimum collection was chosen to increase the number of particles collected on the downstream test filter paper. As indicated in Fig. 12, the H-70 filter paper at a particle velocity of 10 cm/sec was more efficient for the collection of $KMnO_4$ particles than for duraluminum particles in the light microscope range. In addition, the collection efficiency over the entire particle size range (using the $KMnO_4$ aerosol) was greater than 94%.

While no optimum particle size for penetration through the filter media was clearly

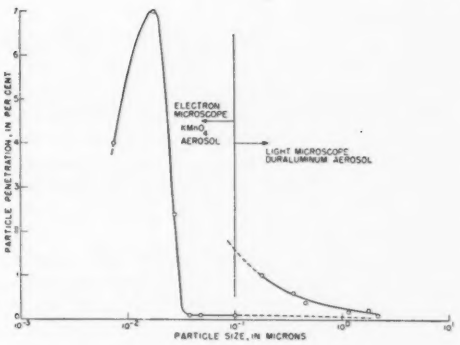


Fig. 14.
Filter efficiency, MSA-1106-B filter paper (10 cm/sec face velocity).

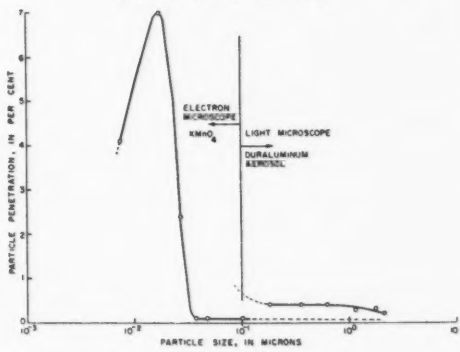


Fig. 15.
Filter efficiency, CC-6 filter paper (10 cm/sec face velocity).

detected, the curve does indicate the possible existence of an optimum particle size in the particle size range below that range which was investigated.

AIR CLEANING FILTER MEDIA: A point of maximum penetration was detected for each of the air cleaning filter media (AEC-1, MSA-1106-B, and CC-6) tested. The optimum particle sizes for AEC-1, MSA-1106-B, and CC-6 filter papers as illustrated in Figs. 13, 14, and 15 were found in the particle size range of 0.01 to 0.02 micron. The efficiencies of the AEC-1, MSA-1106-B, and CC-6 for the collection of particles over the entire particle range were greater than 91.5, 93.0, and 93.0% respectively. The estimated collection efficiencies for these filter media in the light microscope particle size range are indicated by the dashed line.

Conclusions

THE Hollingsworth and Vose-70 filter medium and the air cleaning filter media tested in these experiments are significantly more efficient in the collection of submicron particles than the Whatman-40 and -41 filter papers. However, with a proper selection of the face velocity, relatively high collection efficiencies can be achieved with the use of the Whatman filter papers.

It has been demonstrated that the air sampling media used in these experiments are more efficient in the collection of the liquid $KMnO_4$ particles than in the collection of the solid duraluminum particles. This statement is valid for particle sizes of 0.2 to 3.0 microns. In the particle size range of 0.005 to 0.1 micron, there is some indication that the Whatman-40 and -41 filter papers are more efficient for the collection of duraluminum than for $KMnO_4$ particles. Since the collection efficiency varies significantly with the type of test aerosol used, one may question the reliability of applying the filter collection efficiency data to the collection of contaminated atmospheric dust, having obtained the data by use of another type of aerosol.

The optimum particle size for penetration through the air cleaning and air sampling filter media was detected or indicated in each of the studies conducted. The optimum particle sizes for penetration through the Whatman-40 and -41 filter papers at a velocity of 150 cm/sec are in good agreement with the theory of Davies and Green.

With the experimental knowledge of these points of maximum penetration of particle sizes through the filter media, and with the knowledge of the complete collection efficiency of the filter media, one can choose more rationally the operational velocities for best utilization of each filter medium. With the above knowledge, a more reliable assessment of air-borne concentrations can be made.

Summary

THE Hollingsworth and Vose-70 filter medium and the air cleaning filter media (CC-6, MSA-1106-B, AEC-1) tested in these experiments are significantly more efficient in the collection of submicron particles than the Whatman-40 and -41 filter papers. However, with a proper selection of the face velocity, relatively high collection efficiencies can be achieved even with the use of the Whatman filter papers.

In these filter efficiency studies, all air sampling filter media investigated were more efficient for the collection of liquid $KMnO_4$ particles in the size range of 0.01 to 2.1 microns than for corresponding sizes of solid duraluminum particles.

In the size range of 0.005 to 0.1 micron, the Whatman-40 and -41 filter papers are more efficient in the collection of solid duraluminum particles than in the collection of $KMnO_4$ particles.

The optimum particle size for penetration through air cleaning and air sampling filter media was detected or indicated in each of the studies conducted. The optimum particle sizes for penetration through Whatman-40 and -41 filter papers occurred at approximately 0.03 and 0.02 micron, respectively, at a velocity of 150 cm/sec (the minimum efficiency under these conditions was 90%). These results are in good agreement with the theory of Davies and Green.

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Engineering and Medical Control of Lead Exposure in Patent Annealing and Galvanizing of Wire

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THE END USES of wire are extremely varied and the wire mill must have facilities for producing stock suitable for fluctuating demands of customers as to hardness, finish, and composition. One example of this is the patenting and hot galvanizing department of the rod and wire mill at the Sparrows Point Plant of Bethlehem Steel Company.

This department has the following equipment: reel stands, lead pans, acid bath, galvanizing pans and take-up blocks. There are two separate processing lines which are known as the single galvanizing and double galvanizing lines; this refers to the weight of zinc coating applied (light or heavy). With this equipment four types of products are made: single galvanized wire, double galvanized wire, annealed wire and patent annealed wire.

Various customer specifications demand different physical properties and to furnish these, temperatures of the lead baths range from 800°F to 1600°F.

As shown in Fig. 1, in the original layout of the lines, the wire to be treated was brought into the department at the reel section. The flow of material was to the south through the lead pans reversing over a large drum and then going north over the reels through the acid bath to the spelter pan. Finally, the material went to the blocks which pull the wire through the process and recoil it.

At the time of the original installation the east and north sides of the department were outside walls and the lead pots were heated by gas-fired tube heaters. As production increases were needed, the lead pots were top-fired and the mill expanded to the north and east, effectively isolating the galvanizing department from the outside atmosphere. Canopy type hoods had been installed over the lead and spelter pans in the original installation and were satisfactory until the advent of top-firing of the lead pans and the surrounding of the department by the expanded mill. The canopy hoods over each of the lead pan areas were 63 feet long and nine feet wide.

The situation at that time was as follows: hoods were ineffective due to lack of makeup air; fans were undersized because of combustion products being vented through hoods; extreme heat condition prevailed dur-

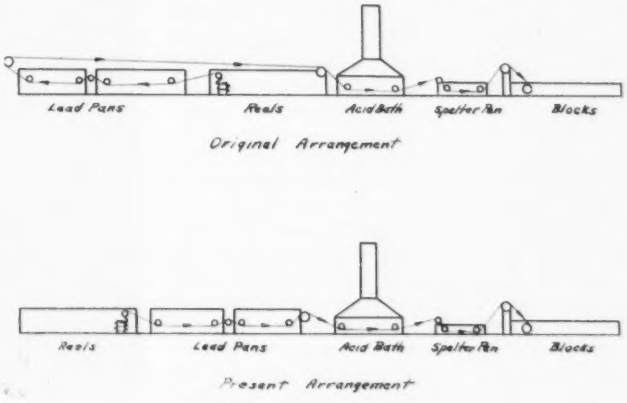


Fig. 1.

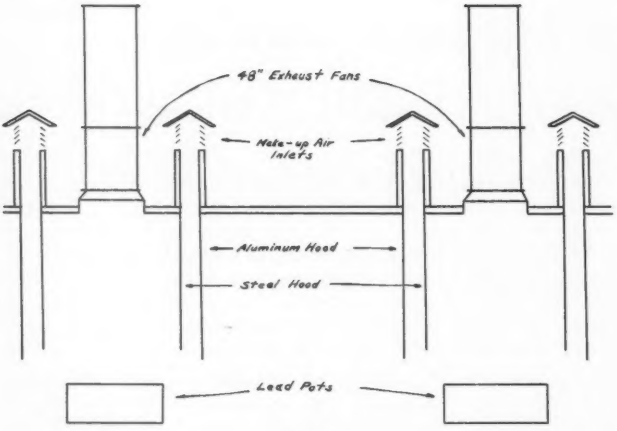


Fig. 2.

ing summer months from normal Middle Atlantic climate, plus radiant heat load from lead pans and canopy hoods.

Atmospheric lead determinations were made on several occasions on the original layout, using the commercially available electrostatic precipitator. Analyses were made by the dithizone method at the Bethlehem Steel Industrial Hygiene Laboratory. These values were found to exceed the recommended level of 0.15 milligrams per cubic meter of air in the area adjacent to the lead pans.

There are two major job classifications in this department, reelers and blockers. The responsibility for material and equipment is divided at the acid baths. Urine and blood lead determinations were run on these employees and, as anticipated, the reelers showed elevated levels while the blockers were in the normal range.

The Program

THE SITUATION was outlined to the operations, engineering and management personnel and the following program was decided upon. The flow of materials was changed to that shown in Fig. 1, with the material flowing in a straight line from south to north. When the lead pans were relocated, the canopy type hoods were also relocated and fan capacity increased by 30%. In addition, a second hood was erected on the east and west exterior sides. This was constructed of corrugated aluminum. The roof between the two hoods was opened to the atmosphere and a louvered penthouse type unit constructed over these openings. Fig. 2 shows a section through the new hoods. Figs. 3 and 4 are interior photographs of the installation.

The present system operates as follows: Summertime: Makeup air is no problem, fans draw all air required from adjacent departments. Lead fumes are controlled and air movement cools reelers. Radiant heat load is eliminated by aluminum hooding and secondary venting of building through intra-hood space occurs. Wintertime: Makeup air is a problem so fans draw air from roof through intra-hood space. Air is slightly tempered by hoods and the reeler is exposed to cold air only when working on lead pans. Drafts in adjacent areas are also minimized. Recirculation of fumes was encountered when rain caps were on fan discharges but this problem has been eliminated with removal of the rain caps. Most

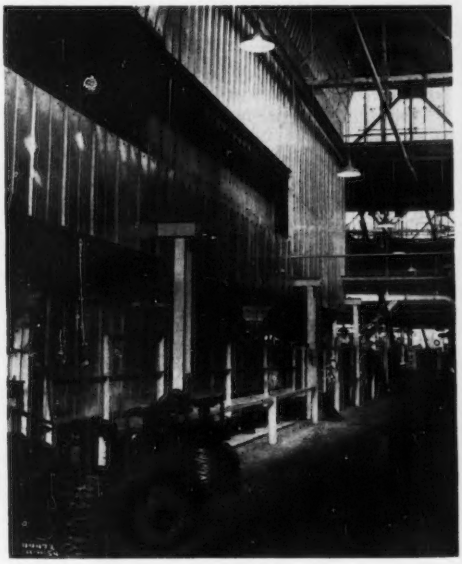


Fig. 3.

recent atmospheric samples averaged less than 0.05 milligrams of lead per cubic meter of air. The system has been operating satisfactorily for over 18 months.

Examination of Workers

IN THIS STUDY 14 workers were examined. Methods of examination included: (1) Adequate history with special reference to the following symptoms: metallic taste, fatigue, weakness, insomnia, headache, vertigo, muscle and joint pain, anorexia, nausea, vomiting, constipation, diarrhea and abdominal cramps. (2) Physical examination with special reference to weight, pallor, tremors, lead line and extensor weakness. (3) Blood studies, including hemoglobin, RBC and stippling count. (4) Urine lead concentration. (5) Blood lead concentration.

Urine and blood lead determinations were made on random samples and we believe along with Meyers that this method of examination offers valuable information on individual variations of lead excretion. Lead intoxication, which depends on individual susceptibility, solubility in the body fluids, and the amount of circulating blood lead, can be prevented by determining hazardous lead absorption accurately and early.



Fig. 4.

TABLE I.
POSITIVE SYMPTOMS IN LEAD EXPOSURE IN PATENT ANNEALING OF WIRE

Anorexia	3	Weakness	0
Headache	2	Insomnia	0
Joint Pain	1	Vertigo	0
Fatigue	1	Constipation	0
Nausea	1	Diarrhea	0
Abdominal Pain	1	Vomiting	0
Metallic Taste	0		

Table I shows symptoms that were positive. There were two with headache, one with joint pain, three with anorexia, one with fatigue, one with nausea and one with abdominal pain. One patient with fatigue, nausea and abdominal pain had an active peptic ulcer. It is interesting to note that after improved working conditions were established, all workers volunteered the information that their appetites were better, that there were no anorexia and nausea and that they felt a general sense of well being. The ulcer patient improved considerably. The few positive symptoms mentioned above were no longer a source of complaint.

Physical findings in this series were essentially normal. Lead line was not found. Extensor weakness was not present. Malnutrition, weight loss, pallor, and tremors were not found. Blood pressure and pulse were normal. We learned from this the importance of periodic examinations, urine and blood determinations.

There were two cases with low hemoglobin. Stippling was not found. One case with low hemoglobin occurred in a patient with active peptic ulcer. It has been reported by many workers that hematopoiesis is disturbed when there is excessive lead absorption. With improved working conditions and less lead absorption there is not only increased production of red blood cells, but less destruction of these cells. Table II shows a comparison of urine and blood lead findings with hemoglobin and red blood cell determinations before and after new preventive measures were installed. It will be noted that urine and blood levels dropped from higher than occupational levels to occupational levels.

Summary

A PROBLEM arising from expansion of plant facilities which caused an exposure to lead fumes and excessive heat in

TABLE II.

A COMPARISON OF URINE AND BLOOD LEAD FINDINGS WITH HB AND RBC DETERMINATIONS BEFORE AND AFTER NEW PREVENTIVE MEASURES WERE INSTALLED

	BEFORE				AFTER			
Patient	Blood Lead Mg/100 gm	Urine Lead Mg/L	Hb Grams	RBC M	Blood Lead Mg/100 gm	Urine Lead Mg/L	Hb Grams	RBC M
J.C.	0.099	0.16	12	4.8	0.083	0.11	16.5	5.4
J.Cu.	0.069	0.40	12.25	4.5	0.063	0.12	13.75	5.65
E.D.	0.081	0.10	13	4.7	0.060	0.07	14.25	5.12
C.H.	0.270	0.26	12.5	5.3	0.060	0.08	14.5	5.3
K.H.	0.083	0.41	13	4.6	0.050	0.06	14.5	4.83
M.H.	0.077	0.23	13	4.61	0.072	0.09	15.5	5.13
E.H.	0.091	0.24	13	4.83	0.043	0.08	14.5	5.1
A.M.	0.075	0.27	11.5	4.24	0.054	0.13	14	4.79
W.N.	0.078	0.13	13	4.6	0.070	0.11	13.5	4.57
D.P.	0.079	0.16	13	4.89	0.057	0.12	14	5.81
P.S.	0.109	0.18	13.5	4.79	0.077	0.26	13.5	4.8
W.T.	0.073	0.16	12.5	4.66	0.051	0.09	13.5	4.77
A.W.	0.074	0.13	13.5	4.85	0.066	0.12	14.25	5.21
W.Z.	0.124	0.28	11	4.1	0.068	0.10	13.5	4.98

a previously satisfactorily controlled operation was detected through routine engineering and medical control programs.

Working conditions were improved by emphasizing unique double exhaust hoods over lead patenting furnaces, and by the use of aluminum shielding to reduce the heat load. As a result, urine and blood lead levels of employees dropped from higher than occupational levels to occupational levels, and there was an improvement in the general health of the workers along with an increase in the Hb and RBC.

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Radiation Protection

ON OCTOBER 20, 1956, the Advisory Health Board of the Pennsylvania Department of Health, adopted regulations on Radiation Protection. These closely follow the model regulation on radiation protection in Handbook 61 of the National Bureau of Standards. Similar regulations have been passed by the States of New York, New Mexico, and Texas. The Pennsylvania regulation requires registration of all sources of radiation with the Department of Health. Under the regulation, it will be necessary for all physicians, dentists, and veterinarians, to register their x-ray apparatus and isotopes with the Department of Health. The Regulation will be administered by the Bureau of Environmental Health and the Division of Industrial Hygiene.

Hygienic and Economic Advantages

OF LOW PRESSURE PNEUMATIC CONVEYING

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THE SUBJECT of pneumatic conveying is appearing more frequently in recent issues of engineering journals and periodicals. In these discussions emphasis has been placed on the material handling and bulk transportation aspects of air conveying. However, numerous hygienic and economic advantages can be realized through the application of pneumatic conveying instead of mechanical conveying of granular, flaked, and powdered chemicals. These advantages are most prominent in applications that are an integral part of an industrial process. It may be said that in process applications the low pressure classification of air conveying is most commonly employed.

Definition and Scope

THERE is no distinct line of demarcation between low pressure and high pressure conveying. In this treatment the line is drawn at the point where the compressibility of air must be considered in flow calculations. Plus or minus zero to 10% of the barometer is normally considered the pressure range in which no serious error is involved in flow calculations based on incompressible fluid flow. At standard barometer this amounts to about ± 40 in. Water Gage.

The ratio of air to material is very often the factor that determines whether a high pressure system will result; here again it is difficult to be specific. However, a figure of 12 cubic feet per pound of material is here proposed, with, of course, no true upper limit; but for those who prefer the offering of limits, the majority of low pressure conveyors do not usually exceed 60 cubic feet per pound.

So far, this classification includes both positive pressure conveying and negative pressure conveying. However, to further pin-point the treatment given in this paper only the negative conveying systems are to be considered. The reason for this is that the system is entirely under suction, thus offering the most hygienic condition.

In summary, then, the systems under discussion are those in which the conveyor system, from the material pickup station to the point of discharge, is below that of the surrounding atmosphere and where the total system loss does not exceed 40 in. W.G. Hence, throughout this paper the term "air conveyor" is to be in accordance with the above definition.

Although it was not set forth in the definition, as perhaps it should have been, it is further specified that virtually 100% separation of particulate matter from the air or gas is affected. This will be true of all examples cited in this discussion.

Components of the Air Conveyor

AN AIR conveyor consists of four basic components: (1) Pickup nozzle or feeder device. (2) Conveyor piping. (3) Receiver-separator. (4) Exhauster.

The design of the material pickup device will vary with the application, yet in no case is the construction more than moderately complex. Basic aerodynamic principles are employed in the design in order to accelerate the feed to the conveying velocity without settling-out of material in the system. It has been found that 16-gauge sheet metal usually offers sufficient strength and ruggedness. See Fig. 1.

Since the conveyor pipe lines are under light pressures the wall thickness need not exceed 16-gauge except where abrasion is a factor. The radius of bends should have a centerline radius of at least three pipe diameters with five preferred and no upper limit. There is no particular pipe joining specification except that no joints should leak. In this case, where virtually 100% recovery or separation of the conveyed ma-

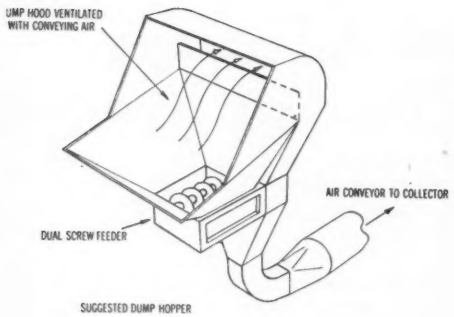


Fig. 1.

terial is required, the cost of this item is greatest. The receiver may consist of a primary mechanical separator followed by a filter type dust arrester or the filter unit only. The filter should be of the continuous cleaning variety such as the reverse jet type in order to maintain a constant pipe line velocity. And the housing construction must have sufficient strength to withstand the design pressure. See Fig. 2.

Exhausters are, in this case, usually of the single stage centrifugal type, but in some instances, where flow rates below 250 CFM are used, a positive displacement type is a more dependable selection. Exhausters with constant pressure characteristics should be avoided since this type will result in conveyor line plugging under even slight overload conditions.

Flexibility of the Air Conveyor

IN GENERAL, the suction system offers flexibility at the material pickup end with little or no flexibility at the delivery end. This is true because the receiver, which consists of a dust collector and exhauster, is a stationary installation. Hence, material can be delivered to one station only, while it may pick up from several locations through a suitable switching arrangement. The reverse is true of positive pressure types where the blower is permanently located at the material loading station. However, a suitable air relief or dust control station is required at each delivery end.

It should be noted at this point that manufacturers and designers of pneumatic conveying systems are offering a great deal of flexibility at both pickup and delivery ends through the use of more complex systems which may or may not involve combinations of pressure and vacuum systems. Space does not permit discussion beyond the realm of the simple system.

Pneumatic vs Mechanical Conveying

IT IS generally well established that more power is required to transport materials pneumatically than mechanically over an equivalent path. Also, mechanical conveyors are inherently capable of handling overload conditions while the pneumatic system is sensitive to overload situations. Although there is no way to reduce power consumption, the designer who is aware of sensitivity to overload may incorporate appropriate control features at the feed end of the air conveyor.

The disadvantages of pneumatic conveyors are more than compensated by their advantages. These advantages will be set forth in the work that follows.

Maintenance of the Air Conveyor

THE MAINTENANCE of the pneumatic conveying system is centered on the dust col-

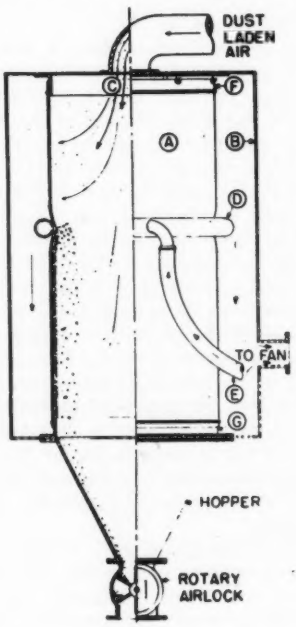


Fig. 2.

lector-receiver. The extent of this maintenance should not be more than that of an ordinary filter type dust collector operated on an equivalent hourly basis. There are instances where power driven devices are employed at the feed end; these of course must be treated as a piece of machinery. Also, in cases where abrasive materials are transported, the pipe bends may require periodic replacement.

Stainless Steel Specifications

WHERE stainless steels are required in a conveyor system, the fabrication of a screw conveyor and bucket elevator becomes costly compared with an equivalent path of light gauge conveyor ducting. In some actual cost comparisons it was found that complete air conveyor systems could be purchased at a cost less than that of a cross screw and bucket elevator, where material contacting surfaces were specified as stainless steel. The cost of the mechanical system did not include dust control accessories. As the transport distance increases the advantage of the pneumatic conveyor increases. The cost of the dust collector-receiver is increased by 12 to 15% where stainless steel is specified.

System Cleaning

THERE ARE various types of processing plants where one system is used to process several types of a similar product such as dyes or pigments where little cross contamination can be tolerated. The headaches of thoroughly cleaning a mechanical conveyor system are readily understandable. Yet satisfactory cleaning of a pneumatic system may be accomplished by conveying relatively small quantities of the following inexpensive materials: (1) leather dust, (2) pearlite, and (3) saw dust. It should be pointed out that it is often necessary to change the filters in the receiver. However, in most systems with which the writer is familiar, the dust collector was of the type consisting of a single filter which is easily interchanged.

Contamination of Product Handled

THE SUCTION type pneumatic conveyor, being in effect a unique exhaust system, is attractive in the eyes of the industrial hygienist who is concerned with the cleanliness and safety and effects on the well-being of operating personnel. Yet there is another hygienic aspect of operations about which the quality control personnel are often vitally concerned—product contamination. Because of certain inherent characteristics of the low pressure pneumatic conveyor, virtually no product contamination can be expected as a result of material transportation. These characteristics are: (1) The path of conveyance is a gas-tight closed duct from the point of pickup to the discharge station. (2) Filtered and/or conditioned air may be supplied at feed end. (3) Since no mechanical parts are involved there is no chance of lubricants contaminating the product. (4) The practical use of lower transport velocities permit use of traps to separate tramp. (5) Permanent magnets may be inserted into the duct to separate magnetic particles.

An Engineering Tool

THE PNEUMATIC conveyor is an engineering tool. Hence the economic and hygienic success of an installation is dependent upon the ingenuity and imagination of the designer. The following paragraphs include descriptions of several low pressure pneumatic systems now successfully operating in process plants throughout this country. You will note that in each installation at least two operations in addition to material conveyance are accomplished.

Sugar Systems—Case I

MOST of the finely pulverized sugar used by the larger bakeries and confectioners is pulverized on the site rather than purchased from the refiners. In the grinding operation the sugar experiences a temperature rise dependent on the power required per pound of ground sugar. The temperature rise through a Mikro Pulverizer is 40 to 50°F. when grinding 6x sugar.

Now it is necessary to cool this pulverized sugar to a maximum temperature in the neighborhood of 100°F. before mixing with other ingredients to form icings and other confections. The ground sugar was stored in portable bins and let stand overnight; the following morning the sugar could be processed. Thus, a one day supply had to be held in storage which required valuable floor space and double labor handling costs.

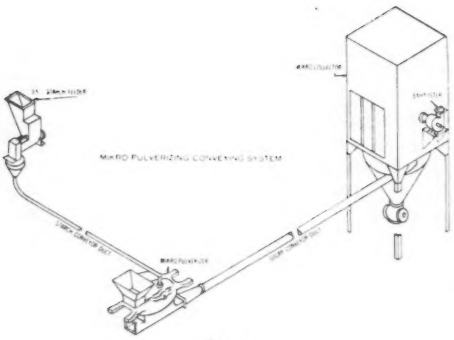


Fig. 3.

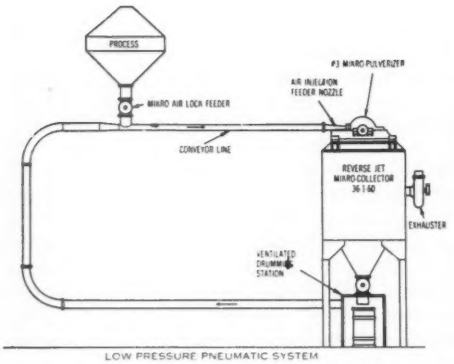


Fig. 4.

Low pressure pneumatic systems, as shown in Fig. 3, are now being installed where the ground sugar is continuously conveyed directly from the mill, which may be located in the vicinity where bulk sugar is received, and transported to the dust collector-receiver, which is located at the process location. The ratio of air to sugar is so selected that the temperature at the delivery end is cool enough to charge direct to the process at a continuous rate if so required. The resultant temperature may be predicted by means of a relatively simple heat balance. In refining operations where starch must be blended with the sugar before packaging 6x sugar the starch is also pneumatically conveyed directly to the grinding chamber at a controlled, continuous rate.

Thus, in this simple pneumatic system several operations are accomplished: (1) Dustless pulverizing. (2) Product cooling. (3) Material handling. (4) Blending.

In addition to performing a multiplicity of operations, it should be pointed out that the conveyor ducting may be run along walls and ceilings, around immovable objects or equipment, and may be passed through floors with relatively little difficulty.

Pneumatic Feeding of Pulverizers—Case II

ALL HIGH SPEED rotating impact pulverizers have the characteristics of low efficiency centrifugal fans. Each pulverizer arrangement, then, has a certain air flow rate associated with its performance. This quality can be changed from a liability to an asset in many instances.

Fig. 4 is a diagrammatic sketch of the method used to put pulverizer air flow to work. A No. 4-TH Mikro-Pulverizer, as shown in the sketch, normally delivers 600 CFM in the range of the most common mill set ups. The pulverizer is mounted directly over and sealed to a reverse jet filter with a single bag 36 inch diameter filter. The usual feed screw and drive assembly is replaced with a specially designed fish-tail injection

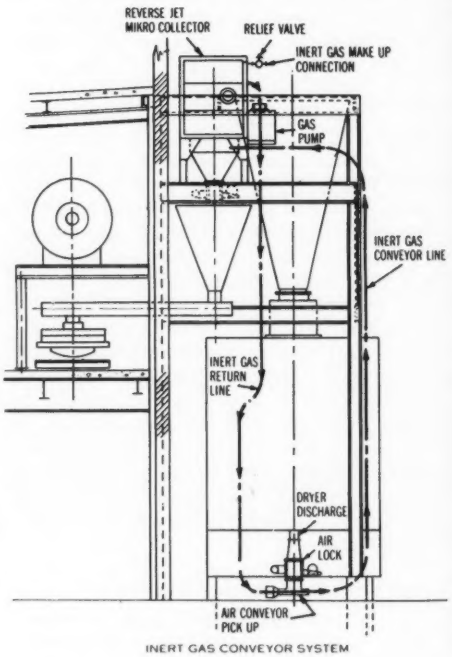


Fig. 5.

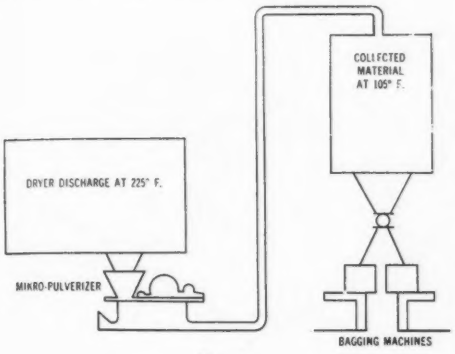


Fig. 6.

nozzle; five inch diameter ducting is connected from the injection nozzle to the discharge of a rotary air lock feeder that is connected to a conical blender. The ducting is expanded to six inch diameter on the upstream side of the material pickup in order to reduce pipe friction, and is returned to exhaust air from a dust hood provided at the drumming station at the discharge of the dust collector A suitable exhaust fan is selected and placed downstream from the collector to overcome the design system resistance.

Again the accomplishments of this low pressure pneumatic system are summarized: (1) Material transport. (2) Feeding pulverizer. (3) Exhaust ventilation. (4) Dustless pulverizing operation.

The success of this operation is manifest in the number of repeat orders received. One dye manufacturer who purchased the first of this type system will soon have a total of seven such systems in operation.

Conveying with Gases Other than Air

THERE ARE a number of dry chemicals that must be handled in a special gaseous atmosphere. The most common application is that of providing an inert atmosphere about explosive materials. Pneumatic conveyors are in service in industrial plants where inert gases replace the usual atmospheric air as the conveyance medium. Fig. 5 is a sketch of a successful installation where the gas employed is nitrogen. In this type operation a closed circuit system is economically necessary; also the entire system must be as gas-tight as possible in order to hold the quantity of make-up gas to a minimum. Rotary air lock feeders are usually selected to feed material into the conveying stream. In closed circuit systems there is always a possibility of temperature build-up; thus it may be necessary to employ a heat exchanger in the return clean gas duct in cases where heat sensitive materials are involved.

Pulverizing chrome green paint pigment is very hazardous under atmospheric conditions. To overcome this danger, one manufacturer enclosed the pulverizer in a chamber to which a proper quantity of scrubbed flue gas is supplied. The product from the pulverizer is continuously conveyed to a dust collector-receiver, and the exhaust gas returned to the stack. A continuous record of the oxygen content is maintained to see that the maximum allowable concentration is not exceeded.

Fig 6 is presented to show how, by proper proportioning of air-material ratios, materials may be cooled to a low enough temperature for direct packaging.

There are a number of materials that tend to cinter if packed at varying tempera-

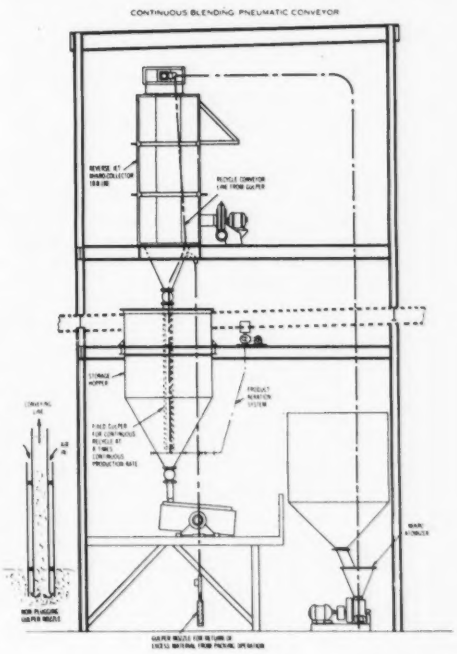


Fig. 7.

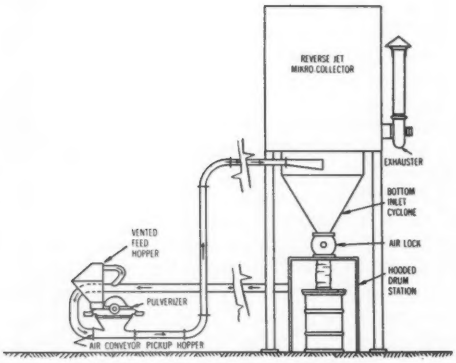


Fig. 8.

tures above ambient; thus by selecting the proper air-material ratio for air conveying the material from the final process station to the packing station, a solution is possible. In many cases the use of refrigerated air has been found practical.

The operation shown in Fig. 7 was devised to produce a smooth quality curve. In this case the product quality varied considerably over short time periods. To affect a blending system to level out quality peaks and valleys, a one hour production quantity is stored in a surge hopper under the conveyor collector; the surge material is recycled at a rate eight times the steady production rate and blended with the steady production line at a junction at the collector inlet. Figs. 8 and 9 show methods of utilizing conveying air to exhaust dusty operations on the same material being handled.

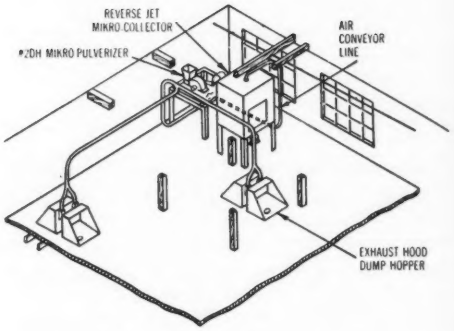


Fig. 9.
Low pressure pneumatic conveyor system. Effects: (1) local exhaust; (2) dustless grinding; (3) material transportation; and (4) complete product recovery.

Summary

THE HYGIENIC advantage of the class of conveyors discussed here lies in the requirement that the entire system from the material pickup point to the delivery station is under suction; thus the operations are completely dustless.

Since low pressure air conveying systems use comparatively large quantities of air for each pound of material conveyed, the alert designer will search for methods of utilizing the available air to accomplish one or more services beyond that of pure material conveyance.

Finally, it should be pointed out that in many instances high vacuum systems have many of the advantages attributed to the low pressure class.

British Occupational Hygiene Society

THE ANNUAL General Meeting of the British Occupational Hygiene Society will be held in Canterbury Hall, Cartwright Gardens, London, W. C. 1. on April 16-17, 1957. The preliminary program indicates that the scientific papers will be directed at the problems of instrumentation in occupational hygiene both in the laboratory and in the field.

Radioactive Diodrast and Rose Bengal Tests for Kidney and Liver Functions

Their Potential Applicability in Industrial Toxicology (Solvents)

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With the Technical Assistance of
PATRICIA PEEL and C. WILLIAM BECKNER, Division of Pharmacology and Toxicology
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DURING the development and initial clinical studies with two new radioisotope tracer tests for kidney and liver functions by using external gamma-ray scintillation counting techniques, it became apparent that these methods could become valuable in studying the toxicity of industrial solvents.[1,2,3] The I^{131}-tagged Rose Bengal Liver Function Test was found more sensitive than the conventional Bromsulfonphthalein (BSP) liver function test in the detection of hepatic damage from carbon tetrachloride in rabbits. The I^{131}-tagged Diodrast Kidney Function Test was only equally or somewhat less sensitive than the Phenolsulfonphthalein (PSP) test in detecting renal damage from mercury poisoning. However, the radioactive test has the advantage of giving functional data rapidly on each kidney individually. This feature is important since kidney disease frequently occurs unilaterally, and exposure to a toxic substance may affect one kidney more than the other.

These tests were developed initially in animal studies and subsequently adapted for use on patients. The purpose of this paper is to describe the procedures for performing the two radioisotope tests and to present preliminary results which indicate the potential value of these techniques in studying the renal and hepatic toxicity of industrial solvents in animals as well as clinically.

Based on work performed at the University of California at Los Angeles under U.S. Atomic Energy Commission Contract No. AT-04-1-GEN-12. Presented at the Seventeenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION at Philadelphia, April 27, 1956.

Materials and Equipment

THE RADIOACTIVE materials, I^{131}-tagged Diodrast and Rose Bengal, are available commercially* in sterile solution. The specific activity of the preparations varies from 0.5 - 1.0 mc/mg. For laboratory or clinical use, the commercial solution is diluted appropriately with isotonic saline to allow intravenous injection of a test dose containing 5-20 μc of radioactivity and 0.5 - 1.5 mg of carrier material. The gamma-ray scintillation counting equipment used in these tests for measurement of radioactivity in blood and organs is identical in principle and design with detectors used for external measurement of I^{131} uptake by the thyroid gland. Here, however, rather than expressing the gamma radioactivity values as a total amount of gamma radiation, measured during a fixed period (1-2 minutes), the impulses are transmitted instead to a ratemeter which, by integrating the accumulation of electrical charges with respect to time, expresses the momentary radioactivity as counts per minute. The levels of radioactivity registered by the Esterline-Angus recorder throughout the period of the test give a graphic tracing of the dynamic changes in the organ or area of tissue under observation.

Fig. 1a shows a satisfactory arrangement of equipment for performing the Diodrast Kidney Function Test in rabbits (the Radio-

*Radioisotope Division of Abbott Laboratories, Oak Ridge, Tennessee.

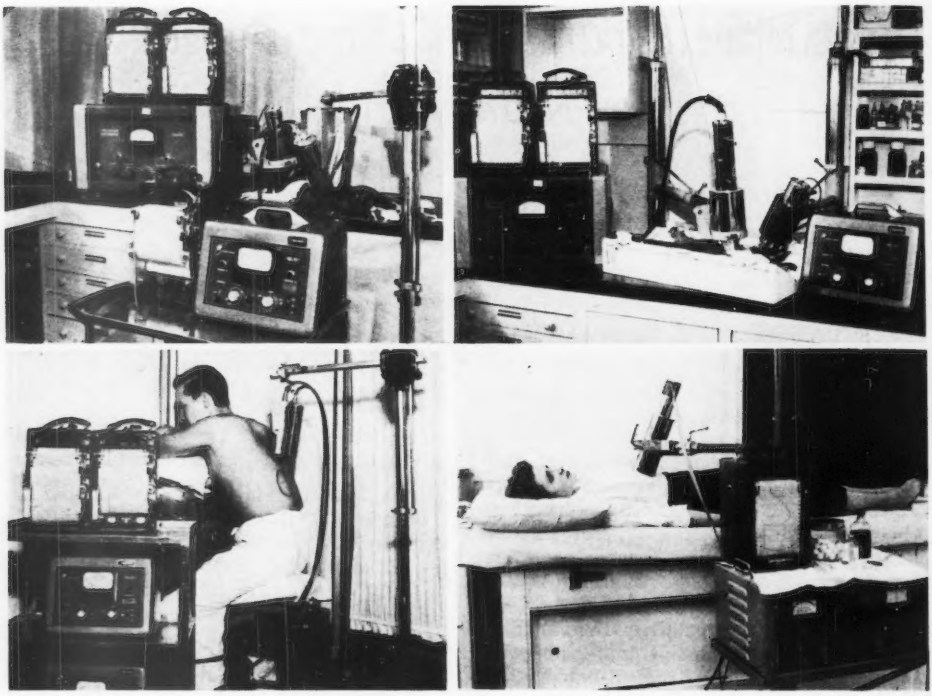


Fig. 1.

active Diodrast Renogram). One detector is positioned directly over each kidney, as located by palpation. A third detector directed over the upper thorax or head is used to measure blood clearance rates of the test material simultaneously. Fig. 1b shows the most feasible method of performing the kidney test in humans, observing the same precautions in positioning the detectors over renal tissue to avoid the main liver mass because of partial uptake of Diodrast by the human liver.

Fig. 1c shows the usual arrangement of equipment for performing the Rose Bengal Liver Function Test in rabbits. The detector is positioned over the lower border of the thoracic cage directed toward the principal mass of the right lobe of the liver and it is tilted cephalad to avoid recording the passage of radioactive dye into the gallbladder and upper intestinal tract. The second detector is positioned over the head (or lower extremity) to record synchronous changes in blood radioactivity. Fig. 1d shows the most convenient arrangement for performing the liver test clinically, observing the same precautions regarding the position and direction of the detector. Since the human liver has a much larger mass, interference from adjacent organs is negligible, if a collimated probe is used. With sensitive detection apparatus, a dose of 1.0 μc/10 kg is adequate.

Results of Diodrast Kidney Function Test

LABORATORY STUDIES: Representative results in rabbits are presented in Fig. 2. The tracing of blood radioactivity in Fig. 2a shows an immediate rise after intravenous injection of the isotope material followed by a rapid precipitous decline, corresponding to removal of the radioactive test substance from the blood stream by the kidney. The uptake-excretion curve recorded over the renal area shows three distinct phases. The first, or vascular phase, is a sudden rise representing the dispersion of radioactive material into the vascular bed of

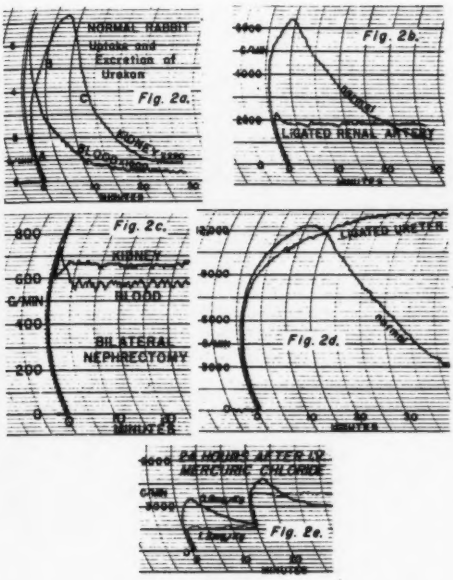


Fig. 2.

the organ. The second, or uptake phase, is a slower but more prolonged rise reflecting the localization of test substance in the kidney parenchymal cells. The third, or excretory phase, shows a decline of radioactivity in the renal area indicating urinary excretion with passage of the labeled Diodrast into the ureter and bladder. A transitory maximum level of radioactivity is attained between the second and third phases of the curve representing a momentary equilibrium between the rates of uptake and excretion. The dynamics of Urokon and Diodrast uptake and excretion by the kidneys of rabbits are practically identical with tracer doses of both agents given intravenously.

Several pathological conditions were simulated surgically to provide known data for interpreting kidney function tracings. Fig. 2b shows the renal uptake-excretion curves for Urokon from an animal having one renal artery ligated. The renogram of the ligated kidney shows no active tubular cell uptake or excretion of tracer test substance because of total vascular impairment. Only a low level of radioactivity is evident, reflecting the dispersion of isotope in the circulation of the tissues adjacent to the vascular kidney.

With bilateral nephrectomy (as in Fig. 2c) no uptake or excretion of radioisotope was observed in the renal area and the blood levels remained high. Ligation of one ureter (Fig. 2d) produced a curve characteristic of obstruction, having a normal vascular segment, a prolonged renal uptake component and no excretion segment. Fig. 2e demonstrates the impairment of kidney function following intravenous administration of mercuric chloride, indicated by depressed renal uptake and retarded excretion. This figure shows typical results of Diodrast and Urokon tests performed in sequence 24 hours after administering intravenously mercuric chloride at two dose levels (0.8 mg/Kg and 1.2 mg/Kg).

The excretion of radioactive Diodrast measured by fractional urine radioassay technique in a normal rabbit is shown along with curves of externally measured kidney and blood radioactivity levels in Fig. 3a, to demonstrate the dynamic physiological relationships involved. In addition, the actual blood clearance rate was determined by measuring radioactivity in serial blood samples.

The discrepancy between the two blood

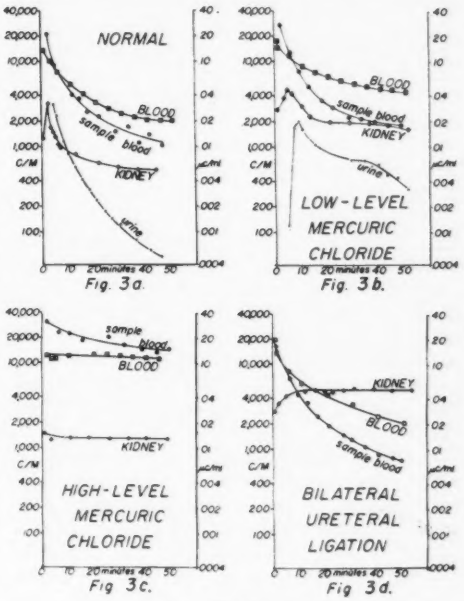


Fig. 3.

curves may be attributed to the inherent capacitor lag in the ratemeter and the recorder and also to possible tissue retention of trace amounts of radioactive material, thereby showing a less rapid rate of blood clearance by external measurements than indicated by sample counting methods. Since the difference between these two curves is relatively small and quite consistent, the measurement of blood radioactivity by external counting methods appears to be satisfactory for most clinical and experimental purposes.

Figs. 3b and 3c show the nephrotoxic effects in rabbits 24 hours after administering mercuric chloride intravenously. With low levels (1 mg/Kg), the renal uptake is decreased and renal excretion delayed, associated with oliguria. The rate of blood clearance is also slightly diminished. In Fig. 3c, after administering a 2 mg/Kg dose of mercuric chloride, the curves indicate gross impairment of blood clearance, minimal renal uptake and no urinary excretion of the test material, due to tubular cell necrosis and obstruction of the renal tubules in histologic sections.

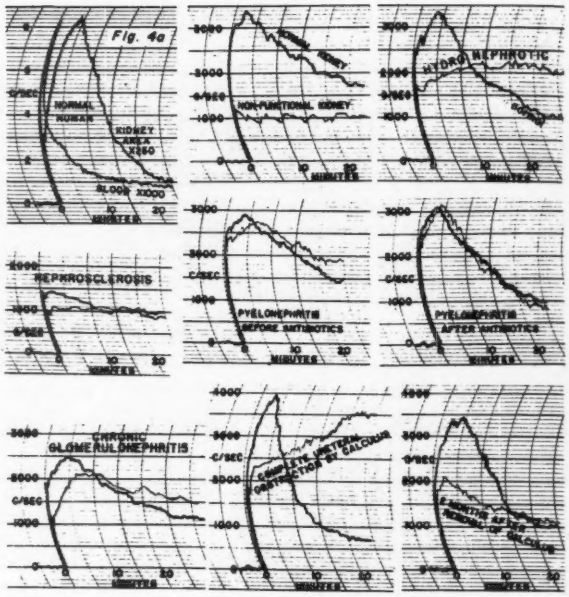


Fig. 4.

By contrast, the findings in an animal with bilaterally ligated ureters (Fig. 3d) show nearly normal rates of blood clearance and renal uptake, indicating the ability of the kidneys to remove the test material from the blood stream even though urinary excretion is blocked completely. Under these acute conditions, complete bilateral ureteral obstruction does not cause immediate impairment of secretory function in the renal tubular cells, and also little, if any, of the test material is reabsorbed from the upper urinary tract.

CLINICAL OBSERVATIONS: The tracings in Fig. 4 show a few of the more characteristic renogram patterns obtained in patients. Fig. 4a shows blood clearance and kidney uptake-excretion in a normal subject for comparison with tracings of patients with various renal disorders. The nature of the functional impairment in each clinical condition is indicated by abnormality of one or more segments of the uptake-excretion curve. Decreased vascularity or general atrophy is manifested by a low initial segment; depressed tubular cell function is indicated by a flattened renal uptake segment, and upper urinary tract obstruction produces an absence of the excretory segment if the lesion causes complete occlusion. Partial obstruction is manifested by flattening of the excretory segment, provided that sufficient tubular cell secretory function remains; otherwise, similar changes in the excretory segment are found in patients with impaired tubular cell function.

Results of Rose Bengal Liver Function Test

PRELIMINARY LABORATORY STUDIES: The liver tracing of a normal rabbit (Fig. 5a) shows a prompt rise of radioactivity during the first minute after intravenous injection, which is followed by a more gradual ascent during the next five to 10 minutes. After a transitory maximum level of radioactivity is reached there is a steady decline indicating the rate at which the test material is excreted from the liver. The pattern of the uptake and excretion of Rose Bengal

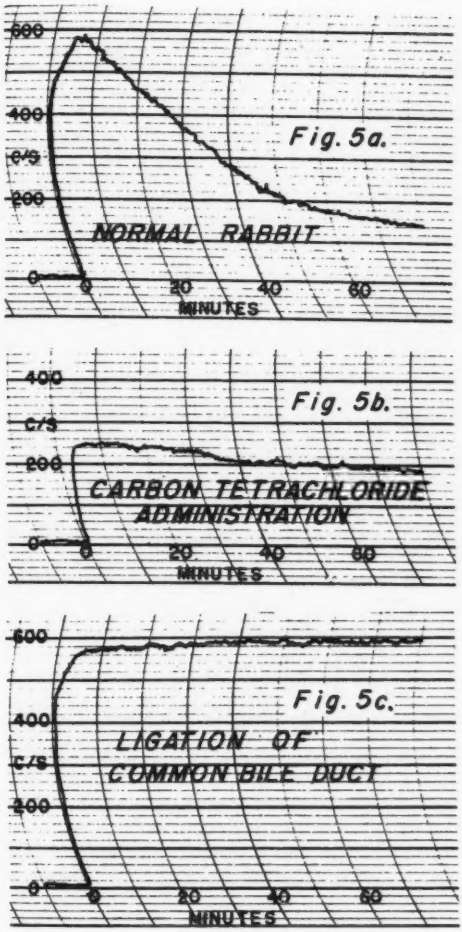


Fig. 5.

over the liver of a rabbit which had received a toxic dose of carbon tetrachloride 24 hours previously is presented in Fig. 5b. The curve shows a decreased rate of liver uptake of the radioisotope and an extremely slow excretion rate. In Fig. 5c, from a rabbit with common bile duct ligation there is a normal liver uptake rate but no evidence of excretion during the test period.

The dynamic relationships of blood clearance, liver uptake-excretion and biliary flow rates are demonstrated in Fig. 6, in animals in which the common bile duct has been cannulated to determine exact rates of biliary excretion and wherein blood clearance has been determined both externally by a gamma-ray scintillation detector positioned over the upper thorax or head and by measuring the radioactivity of serial blood samples obtained from a cannulated carotid artery. In a normal animal (Fig. 6a) the level of blood radioactivity rises almost immediately after intravenous injection and falls rapidly during the next 10 to 15 minutes. The shape of the liver uptake curve is almost a mirror image of the blood clearance curve. As the rates of blood clearance and liver uptake equal the rate of biliary excretion, the radioactivity recorded over the liver area reaches a transitory equilibrium. With discharge of the labeled dye into the biliary passages the level of hepatic radioactivity declines at a steady rate which is parallel to the rate of decreasing radioactivity measured in bile samples. This relationship demonstrates that the excretory leg of the liver uptake-excretion curve is an accurate index of the rate of bile flow. In Fig. 6b and 6c the relationships between rates of blood clearance and hepatic uptake and excretion are shown from animals which had received carbon tetrachloride 24 hours pre-

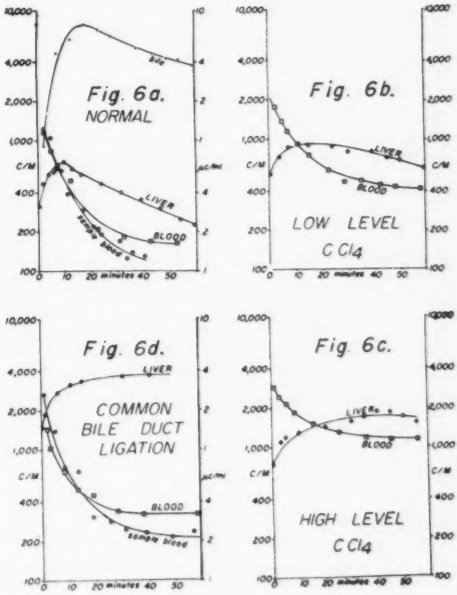


Fig. 6.

viously at low (30 mg/Kg) and high (800 mg/Kg) levels, respectively. The rates of blood clearance, diminished liver uptake and excretion are altered in relation to dosage of carbon tetrachloride. Fig. 6d demonstrates the effects of acute biliary obstruction produced by surgical ligation of the common bile duct. The rates and magnitude of Rose Bengal blood clearance and liver uptake are normal despite complete retention of the test material in the liver. Chronic biliary obstruction, on the other hand, is known to produce inflammatory and subsequent fibrotic changes which result in the development of biliary cirrhosis, a condition indistinguishable by functional tests from various other types of cirrhosis.

DETECTION OF LIVER DAMAGE IN RABBITS FROM CARBON TETRACHLORIDE POISONING: Four groups of animals were treated with carbon tetrachloride in olive oil administered by gastric intubation at dose levels of 3, 80 and 160 mg/Kg. Twenty-four hours after administration, six rabbits from each group were tested with 5 mg/Kg of Bromsulfonphthalein, using as end-point the retention of dye (μg/ml of serum) 30 minutes after intravenous injection. The result in each animal was compared with the result of an identical BSP test performed prior to the carbon tetrachloride administration.

The remaining animals in each group were tested at the same 24-hour interval after poisoning using 10 μc of I^{131}-labeled Rose Bengal in 0.5 to 5.0 mg of carrier dye solution. The tracing from each animal was compared with its own control tracing of an identical test performed prior to carbon tetrachloride administration.

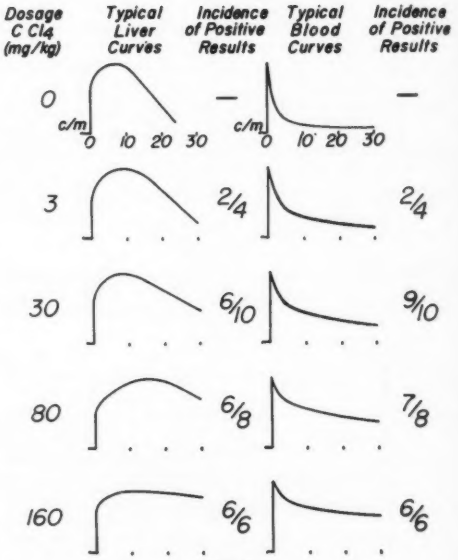


Fig. 7.

Results of the radioactive Rose Bengal test (presented in Fig. 7) show progressive changes of liver uptake-excretion and blood clearance curves as the dose of carbon tetrachloride is increased from 3 to 160 mg/Kg. The most readily measurable change of the liver tracing in poisoned animals is flattening of the excretion segment. The blood curves show progressive reduction of

TABLE I.
COMPARISON BETWEEN BROMSULFONPHTHALEIN BLOOD RETENTION AND ROSE BENGAL I^{131} LIVER FUNCTION TESTS FOR DETECTING LIVER DAMAGE FROM CARBON TETRACHLORIDE IN RABBITS

Bromsulfonphthalein Results			Levels of CCl_4 Poisoning	Rose Bengal I^{131} Results	
Blood Retention μg/ml Serum at 30 Min				Incidence of Positive Results	
Control Range	Range After Poisoning	Incidence of Positive Results	mg/Kg	From Liver Curves	From Blood Curves
0-17	—	0/24	Controls	0/28	0/28
0-17	0-4	0/6	3	2/4	2/4
0-17	0-51	1/6	30	6/10	9/10
0-17	0-34	2/6	80	6/8	7/8
0-19	3-52	4/6	160	6/6	6/6

NOTES:
1. Separate groups of animals were used for Bromsulfonphthalein and Rose Bengal Tests.
2. Carbon Tetrachloride was given in olive oil by gastric intubation in the doses recorded.
3. Each animal was tested before and 24 hours after poisoning.
4. Results in poisoned animals were compared with tho e from the same animals *before* poisoning.
5. Values from poisoned animals were considered positive if they exceeded the upper limits of control range.
6. Bromsulfonphthalein - 5 mg/Kg.

clearance rates and increasingly higher blood retention during the first few minutes after injection, as well as greater retention at 20 to 30 minutes, in relation to the dose of carbon tetrachloride administered. The blood changes reflect the inability of the damaged liver cells to remove the dye from the circulation, whereas the flattening of the excretion segment in the liver tracing indicates impairment of bile formation and or bile flow.

Table I shows the relative sensitivity of the Bromsulfonphthalein test as compared with the radioactive Rose Bengal tests in detecting liver damage from carbon tetrachloride. The Rose Bengal procedure shows a higher incidence of altered function at the 30 mg/Kg level of poisoning than the BSP test does at the 160 mg/Kg level. The BSP test fails to demonstrate any liver cell damage at the 3 mg/Kg level, whereas the Rose Bengal tests are positive in two of four animals.

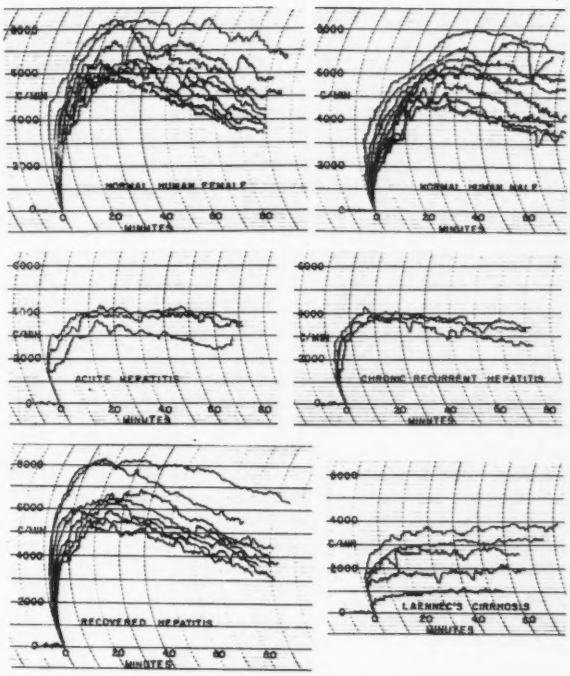


Fig. 8.

These results indicate that the radioactive Rose Bengal tests are at least five times as sensitive as the standard Bromsulfonphthalein procedure when used for detecting liver cell injury in animals poisoned with carbon tetrachloride. Furthermore, the radioactive dye tests provide additional data on the rates of bile formation and/or bile flow not measurable by other methods.

CLINICAL OBSERVATIONS: The radioactive Rose Bengal Liver Uptake-Excretion Test has been performed on 70 patients, including subjects with normal liver function and individuals with liver disease of various types and severity. Test results presented in Fig. 8 demonstrate the similarity between the tracings of normal subjects and those of patients who have recovered from hepatitis. The patterns of the curves from patients having Laennec's cirrhosis are strikingly different, in that they have abnormally low vascular segments (first minute rise), and extremely slow rates of liver uptake. Patients with acute or chronic hepatitis have depressed vascular segments and also a decrease in the rates of liver uptake and excretion.

One of the major advantages of the radioisotope tracer test is that it can be performed repeatedly during the course of liver disease even in the presence of severe jaundice. When used in this manner, it provides data simultaneously on changes in liver vascularity, polygonal cell function and on bile formation and/or biliary excretion. Although no patients with chemotoxic hepatitis have been studied, it appears likely from the animal experiments that the test should provide a sensitive and practical method for detecting liver injury experimentally and clinically following exposure to hepatotoxic agents.

Summary

TWO recently developed radioisotope tracer tests for estimating liver and kidney functions externally are described. Both test procedures are based on the same principles and similar equipment is used. Following in-

travenous injection of the radioactive tracer material, the rates of organ uptake-excretion and blood clearance are measured simultaneously with sensitive gamma-ray scintillation counters directed over the appropriate body areas, and the changing levels of radioactivity are recorded continuously throughout the duration of the test.

From preliminary experimental results in animals poisoned with mercuric chloride and carbon tetrachloride and from clinical experience with both test procedures, it appears that these radioisotope tests may have considerable value in investigating the relative renal and hepatic toxicity of various industrial solvents in animals and in man. The Radioactive Rose Bengal Liver Function Test appears to have greater applicability in this field than the Radioactive (I^{131}-labeled) Diodrast Kidney Function Test because the Rose Bengal method is at least five times as sensitive as the standard Bromsulfonphthalein test in detecting carbon tetrachloride liver damage in rabbits.

Acknowledgement

THE AUTHORS are grateful to Dr. Franz Bauer, Chief of the Radioisotope Service, Veterans Administration Center, Los Angeles, and members of his group for their cooperation in facilitating the clinical studies; to Dr. Chester C. Winter of the Urological Service, Veterans Administration Center, for performing the clinical studies with the Radioactive Diodrast Renal Function Test; to Dr. Willard E. Goodwin, Professor of Urology and Surgery, UCLA, and Chief of the Urology Service, Veterans Administration Center, for facilitating the clinical investigation of the latter test; to Dr. Donalee Tabern and Mr. Butler Sanchez of Abbott Laboratories for generous supplies of I^{131}-labeled Rose Bengal and Diodrast from the Department of Radio-Pharmaceuticals, Oak Ridge, Tennessee; to Drs. Benedict Cassen and Norman S. MacDonald of the Atomic Energy Project, University of California at Los Angeles, for valuable advice during the project and for editorial assistance during preparation of the manuscript; and finally to Messrs. Clifton W. Reed and Lawrence R. Curtis of the R-C Scientific Instrument Company for use of a set of their scintillation counting equipment employed in the clinical studies.

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Municipal and Sanitary Engineering Conference

THE TENTH Municipal and Sanitary Engineering Conference will be held on the campus of the University of Florida March 19 and 20, 1957. The meeting will be centered around the theme "The Impact of Industrial Expansion on Man and His Environment." Some of the subjects on which papers will be presented include factors in plant location, water resources, liquid waste disposal, health problems, industrial hygiene, air pollution, and industrial application of nuclear energy. A registration fee of $8.00 includes a ticket to the banquet and a copy of the conference proceedings when published. All who are interested are invited to attend. Further information may be obtained from DR. E. R. HENDRICKSON, Conference Chairman, University of Florida, Gainesville, Florida.

Maximum Permissible Radiation Exposures to Man

A Preliminary Statement of the
National Committee on Radiation Protection and Measurement

SINCE the publication of the National Bureau of Standards Handbook 59 on Permissible Dose from External Sources of Ionizing Radiation, the National Committee on Radiation Protection and Measurement (NCRP) has continued the study and review of its recommendations, particularly with respect to genetic effects and the possible shortening of average life expectancy due to radiation exposure of a larger fraction of the population.

The NCRP proposals resulting from these studies had an important influence on the decisions reached by the International Commission on Radiological Protection (ICRP) in Geneva in April, 1956, which resulted in a general lowering of the maximum permissible accumulated dose (MPD) for occupational radiation exposures as well as for exposures of the population as a whole. These changes are in accord with the informal agreements reached by the ICRP in Stockholm in 1952.

The NCRP has now agreed upon the formulation of revised recommendations on maximum permissible doses which integrate the national and international views for practical application. The Committee is pleased to note that the findings of the ICRP are reinforced by the important information and data provided in the subsequent reports of the National Academy of Sciences and the British Medical Research Council.

The changes in the accumulated MPD are not the results of positive evidence of damage due to use of the earlier permissible dose levels, but rather are based on the desire to bring the MPD into accord with the trends of scientific opinion; it is recognized that there are still many uncertainties in the available data and information. Consideration has also been given to the probability of a large future increase in radiation uses. In spite of the trends, it is believed that the risk involved in delaying the activation of these recommendations is very small if not negligible.

Conditions in existing installations should be modified to meet the new recommendations as soon as practicable, and the new MPD limits should be used in the design and planning of future apparatus and installations. Because of the impact of these changes and the time required to modify existing equipment and installations, it is recommended on the basis of present knowledge that a conversion period of not more than five years be adopted within which time all necessary modifications should be completed.

Definitions

FOR THE PURPOSES of this preliminary statement, the following tentative definitions are given:

Controlled Area. A defined area in which the occupational exposure of personnel to radiation or to radioactive material is under the supervision of a radiation safety officer. (This implies that a controlled area is one that requires control of access, occupancy, and working conditions for radiation protection purposes.)

Workload. The output of a radiation machine or a radioactive source integrated over a suitable time and expressed in appropriate units.

Occupancy Factor. The factor by which the workload should be multiplied to correct for the degree or type of occupancy of the area in question.

RBE Dose. RBE stands for relative biological effectiveness. An RBE dose is the dose measured in rems. (This is discussed in the forthcoming report of the International Commission on Radiological Units and Measurement.)

MPD Recommendations for Occupational Conditions (Controlled Areas)

ACCUMULATED DOSE: The maximum permissible accumulated dose, in rems, is equal to five times the number of years of age beyond 18, provided no annual increment exceeds 15 rems. Thus the accumulated MPD = 5 (N - 18) rems where N is the age and greater than 18. This applies to all critical organs except the skin, for which the value is double.

WEEKLY DOSE: The previous permissible weekly whole-body dose of 0.3 rem, and the 13-week dose of three rems when the weekly limit is exceeded, are still considered to be the weekly MPD with the above restriction for accumulated dose.

EMERGENCY DOSE: An accidental or emergency dose of 25 rems to the whole body, occurring only once in the lifetime of the person, shall be assumed to have no effect on the radiation tolerance status of that person. (See National Bureau of Standards Handbook 59.)

MEDICAL DOSE: Radiation exposures resulting from necessary medical and dental procedures shall be assumed to have no effect on the radiation tolerance status of the person concerned.

MPD Recommendations for Whole Population

THE MAXIMUM permissible dose to the gonads for the population of the United States as a whole from all sources of radiation, including medical and other man-made sources, and background, shall not exceed 14 million rems per million of population over the period from conception up to age 30, and one-third that amount in each decade thereafter. Averaging should be done for the population group in which cross-breeding may be expected.

Recommendations for Internal Emitters

IN CONTROLLED areas, the permissible radiation levels for internal emitters will conform to the general principles outlined above. Where the critical organ is the gonad or the whole body, the maximum permissible concentrations of radionuclides in air and water will be one-third the values heretofore specified for radiation workers. Where single organs other than the gonads are regarded as the critical organ, the present maximum permissible concentrations will continue. For individuals outside of controlled areas, the maximum permissible concentrations should be one-tenth of those for occupational exposures. (Other changes in the maximum permissible concentrations for radionuclides may be introduced because of additional information developed since the publication of National Bureau of Standards Handbook 52.)

Discussion of Revised Recommendations

THE MPD for occupational exposure is based on the absence of detectable injury to the individual. It remains at its present level of 0.3 rem/week for the whole body. Where the dose in any week exceeds this value, a dose of three rems in 13 weeks may be accepted. The 13-week period may start at the beginning of the calendar quarter or the beginning of the week during which the permissible weekly dose was exceeded.

The rules given in Handbook 59 will be continued for operational and administrative purposes, but some of the rules will be modified by provisions related to an average yearly limitation of occupational exposure to external sources of ionizing radiation of five rems to the blood-forming organs, gonads, and lens of the eyes, and of 10 rems to the skin. The use of "five rems" in the statement of the revised rules is for the purpose of design and administration. The critical limitation will be that defined for the total accumulated dose in the paragraph on ACCUMULATED DOSE above.

If a person's occupational exposure is documented or otherwise known with reasonable certainty, he may be permitted to use his reserve exposure in accordance with the paragraphs on ACCUMULATED DOSE and WEEKLY DOSE above. In all other cases, he shall be assumed to have received his maximum accumulated dose as indicated in ACCUMULATED DOSE paragraph above.

It is considered that with the current and proposed low levels of occupational exposure, it is presently not necessary to make special allowance for medical exposure in conjunction with occupational exposure. This consideration may later become important. The effects of medical exposures have long been considered by this Committee to be the responsibility of the attending physician; it is his responsibility to evaluate medical radiation exposure in relation to

the health of the individual. (See National Bureau of Standards Handbook 59.)

In the determination of the population dose in the vicinity of radiation sources, proper consideration should be given to occupancy factor and to workload. The exposure of individuals outside of controlled areas may be integrated over periods up to one year.

While at the moment it is not feasible to determine the average exposure for the population with any reasonable accuracy, the adoption of some figure is necessary for planning purposes. For the immediate future, it may be assumed that the total integrated RBE dose received by all radiation workers will be small in comparison with the integrated RBE dose of the whole population.

Furthermore, persons outside of controlled areas, but exposed to radiation from a controlled area, constitute only a small portion of the whole population. Therefore, if this small portion is assumed to receive yearly an average per capita dose of 0.5 rem, the total dose to the whole population from man-made radiations is not likely to exceed 10 million rems per million of population up to age 30. (This assumes a dose of four million rems per million of population over this age period from background radiation.)

Packaged Water for Disaster Areas

THE FEDERAL Civil Defense Administration has enlisted the support of the nation's dairies and their allied industries in a program designed to assure the speedy delivery of safe drinking water, packaged like milk, to stricken communities in the event of natural disaster. It proposes that in any emergency, dairies in areas affected would package water in containers usually used for milk for shipment by air, rail, truck or water to the disaster regions. It would be the responsibility of the civil defense director in any community where the water supply was knocked out to determine the need for drinking water and the amount required. He would appeal to the nearest dairies still in operation and make arrangements for packaging and shipping the drinking water to his community. The idea of using drinking water packaged in milk containers to aid a community was introduced at Stroudsburg, Pennsylvania, in August, 1955, when that city was flooded by the torrential rains of Hurricane Diane. An Allentown dairy supplied cartons and also filled them with water to avoid the contamination that might have resulted from manual filling in Stroudsburg. The filled cartons were trucked to Stroudsburg and distributed to flood victims. After the success of the Stroudsburg experiment, FCDA officials consulted with representatives of the dairy industry and health and relief organizations with a view to perfecting the program so that it could be used in areas hit by flood, fire, hurricane, tornado, earthquake, explosion, or drought.

HYGIENIC GUIDE SERIES

OZONE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 0.1 parts of gas per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation*: Animal studies and studies of human experience.[5,7,8]

B. SEVERITY OF HAZARDS:

(1) *Health*: High, for all types of exposures. Those of relatively short duration to concentrations at or above 1 ppm produce dryness of the eyes and respiratory tract, and headache. Longer exposures or higher concentrations may result in severe or even fatal effects from injury to the lungs.

(2) *Fire*: Ordinarily none, unless in extremely high concentrations. As a liquid it is a highly dangerous explosive.

C. SHORT EXPOSURE TOLERANCE: Safe level unknown, but 2 ppm probably safe for a few minutes, provided respiratory infection, either latent or manifest, is not present.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown, but 50 ppm for 30 minutes might be expected to produce fatal results.

II. Significant Properties

Ordinarily, ozone is a colorless gas condensable to a dark blue liquid at -112°C. Strong absorption at 2,537 A. Characteristic odor detectable by most individuals at 0.02-0.05 ppm.

Chemical formula:	O_3
Molecular weight:	48
Relative vapor density:	1.65 (air = 1)
Odor:	pungent, characteristic
Solubility:	1 g/l[4] in water

At 25°C and 760 mm Hg,

1 ppm of vapor:	0.00196 mg/liter
1 mg/liter:	509 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: Produced by electric discharge radiations below 2000 A. Present in welding fumes, especially those from inert gas-shielded arc-welding, in oxidizing smog, and in upper atmosphere at 65,000 feet.

B. EVALUATION OF EXPOSURES:

(1) *Chemical*: Sampling and analysis of atmospheric concentrations may be done by the method of Smith and Diamond,[6] as modified by Byers, Saltzman and Hyslop.[3] The method consists of absorbing ozone in alkaline potassium iodide, neutralizing, and measuring the intensity of color development.

(2) *Instrumentation*: Continuous-recording devices are available that measure ozone in concentrations of a few parts per hundred million. (Borman Engineering, Inc., North Hollywood, Calif.; Harold Kruger Instruments, San Gabriel, Calif.; Beckman Instruments, Fullerton, Calif.).

A direct reading instrument, utilizing the oxidant effect on rubber,[2] is available (B. F. Goodrich Research Center, Brecksville, Ohio).

C. RECOMMENDED CONTROL PROCEDURES: Maintain air concentrations below 0.1 ppm. All exposed personnel should be trained to detect low concentrations of ozone in the atmosphere and in the use of protective equipment if concentrations approach or exceed 1 part per million.

IV. Specific Procedures

A. FIRST AID: With any obvious exposure, remove individual from contaminated atmos-

phere. Keep exposed person at complete rest until seen by a physician.

B. BIOCHEMICAL ASSAY: None.

C. SPECIAL MEDICAL PROCEDURES:

(1) *Preplacement*: Individuals with pre-existing pulmonary disease, or those highly susceptible to respiratory infection, should not be exposed to ozone.[9]

(2) *Treatment of Acute Exposures*: Place patient at immediate and complete bed rest. Immediately perform medical examination to evaluate the degree of pulmonary injury. If early, transient, asthmatic breathing is present, pulmonary edema will occur later. Such patients should be kept under constant medical supervision until indications of edema have disappeared. The blood pressure, pulse, and respiratory rates should be noted at frequent intervals. Blood studies, particularly total white, differential, and platelet counts, may be useful in determining pulmonary damage. Oxygen should be used as indicated.

(3) *Periodic Medical Examinations*: Individuals repeatedly exposed to low concentrations of ozone should have medical examinations, including chest x-rays. Those who have had acute exposures should be followed by medical examination.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health*, 14:187, 1956.
2. BEATTY, J. R., and JUVE, A. E.: *Rubber World*, November, 1954.
3. BYERS, D. H., SALTZMAN, B. E., HYSLOP, F. L.: Report of Environmental Research Laboratory, Department Public Health, University of Washington, May 10, 1955.
4. HANN, V. A., MANLEY, I. C.: *Encycl. Chem. Technol.*, 9:735, 1952, Interscience Encycl., Inc., New York.
5. KLEINFELD, M.: *Am. J. Med. Sci.*, 231:638, 1956.
6. SMITH, R. G., DIAMOND, P.: *AIHA Quart.*, 13:252, 1952.
7. STOKINGER, H. E.: *AMA Arch. Ind. Hyg. & Occup. Med.*, 9:366, 1954.
8. STOKINGER, H. E., WAGNER, W. D., WRIGHT, P. G.: *AMA Arch. Ind. Health*, 14:158, 1956.
9. STOKINGER, H. E.: Paper presented at 1956 Air Pollution Symposium, American Chemical Society, Atlantic City, September 18, 1956.

ACETONE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 1000 parts of vapor per million parts of air, by volume (ppm).[1,5]

(1) *Basis for Recommendation*: Sensory response and comfort. The 1000 ppm threshold limit is well below a concentration capable of producing narcotic symptoms or mucuous membrane irritation.

B. SEVERITY OF HAZARDS:

(1) *Health*: Low, for both acute and chronic exposures. This is one of the least hazardous industrial organic solvents. It is practically devoid of inhalation hazard. In very high concentrations, acetone acts principally as a narcotic.

(2) *Fire*: Severe. Explosive limits are 2.5 to 12.8% by volume. Flash point is -17.8°C (0°F) (closed cup).[4]

C. SHORT EXPOSURE TOLERANCE: 10,000 ppm probably endurable 30-60 minutes without symptoms. Some transient eye and nasal irritation.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown.

II. Significant Properties

A clear, colorless, flammable liquid, with a burning taste and a characteristic sweetish odor.

Chemical formula:	CH_3COCH_3
Molecular weight:	58.08
Specific gravity:	0.792
Boiling point:	56.5°C
Relative vapor density:	2.00 (air = 1)
Solubility:	Soluble in all proportions in water, alcohol and ether
At 25°C and 760 mm Hg,	
1 ppm of vapor:	0.002372 mg/liter
1 mg/liter	422 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: May be recognized by characteristic odor. Used widely as a solvent in the paint, plastics, rubber, cement, and chemical manufacturing industries.

B. EVALUATION OF EXPOSURE:

(1) *Chemical*: Collection in water, on silica gel, or in evacuated bottles, followed by analysis by the salicylaldehyde[3] or the 2,4-dinitrophenyl hydrazine method.[2]

C. RECOMMENDED CONTROL PROCEDURE: Good general ventilation and enclosure of process will normally maintain workroom atmospheric concentrations below recommended level.

IV. Specific Procedures

A. FIRST AID: No first aid measures are usually needed. In the event of prolonged exposure to very high concentrations with narcotic symptoms, remove from exposure and secure medical advice. With extensive liquid contact with the skin or clothing, remove clothing and flush underlying areas with water. In the case of any eye contact with the liquid, flush eye with copious amounts of water.

B. BIOCHEMICAL ASSAY: Determination in the blood, urine, and exhaled air may be made, but are usually unnecessary.

C. SPECIFIC MEDICAL PROCEDURES: None.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health*, 14:187, 1956.
2. GREENBERG, L. A., and LESTER, D.: *J. Biol. Chem.*, 154:177-190, 1944.
3. KORENMAN, J. M.: *Arch. f. Hyg.*, 112:235, 1934.
4. National Fire Protection Association: National Fire Codes, Vol. 1, p. 464.
5. OGLESBY, F. L. (Tennessee Eastman Corp.): Paper presented at 1949 meeting of AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Detroit, Unpublished.

ACRYLONITRILE
(Propenenitrile, Vinylcyanide)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 20 parts of vapor per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation*: Animal experiments and observation of humans.[2,5,7,10]

B. SEVERITY OF HAZARDS:

(1) *Health*: Severe for acute; moderate, for chronic exposures. No definite evidences of cumulative action have been observed. Toxic action believed to be similar to that of hydrogen cyanide, *i.e.*, enzyme inhibition of cellular metabolism. Readily absorbed through the skin. May cause contact dermatitis.

(2) *Fire*: Severe fire and explosion hazard. Flash point is -1°C(30°F) (closed cup). Explosive limits: 3% to 17% by volume in air at 25°C. Ignition temperature: 481°C (898°F).

C. SHORT EXPOSURE TOLERANCE: Not known.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Not known.

II. Significant Properties[3,9]

A clear, colorless liquid, at ordinary temperatures, with characteristic odor. Technical product may have slight yellow tinge.

Chemical formula:	CH_2CHCN
Molecular weight:	53.06
Specific gravity:	0.823 at 4/4°C
Boiling point:	77.3°C (171°F) at 760 mm
Relative vapor density:	1.83 (air = 1.0)
Vapor pressure:	83 mm at 20°C
Solubility:	9.3% by weight in water (at 77°F)
At 25°C and 760 mm, Hg,	
1 ppm of vapor:	0.00217 mg/liter
1 mg/liter:	460.5 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: Acrylonitrile is used in the production of some types of synthetic rubber, plastics, and in organic syntheses. It may create a serious problem in the laboratory unless kept in tightly closed containers.

B. EVALUATION OF EXPOSURE:

(1) *Instrumentation*: Polarography,[4] following collection in 95% ethyl alcohol, or ultraviolet spectrophotometry,[5] following collection in water.

(2) *Chemical*: Collection in dilute alkaline potassium permanganate, and subsequent colorimetry.[8] This is not specific for acrylonitrile.

C. RECOMMENDED CONTROL PROCEDURES:

Maintain workroom atmospheres below 20 ppm. Enclosed systems and/or ventilation may be required. Organic vapor canister masks or fresh air masks should be used where the concentration of vapors cannot be adequately controlled. Clothing and shoes wet with acrylonitrile should be removed at once, washed thoroughly, and dried before being worn again. Kits containing amyl nitrite, sodium nitrite, and sodium thiosulfate should be readily available.

IV. Specific Procedures

A. FIRST AID: Removal to a non-contaminated area should be prompt. Summon medical assistance. Artificial respiration should be started at once if respiration has ceased. Clothing wetted with acrylonitrile should be removed immediately and the skin thoroughly washed with soap and warm water. In case of eye contact, irrigate immediately with large quantities of water for a minimum of 15 minutes, and preferably for 30 minutes if no physician is available.

B. BIOCHEMICAL ASSAY: Acrylonitrile is hydrolyzed and metabolized to thiocyanate, which is then excreted in the urine. No quantitative relationship between exposure to acrylonitrile and thiocyanate concentration in the urine has been established.

C. SPECIAL MEDICAL PROCEDURES:

(1) *Preplacement*: Persons with a history of fainting spells,[9] such as occur in various types of cardiovascular and nervous disorders, and those with pre-existing renal or liver disease,[3] should probably be excluded from the use or handling of acrylonitrile.

(2) *Treatment*: Amyl nitrite inhalations and sodium nitrite-sodium thiosulfate injections should be used promptly.[6,11] If swallowed, vomiting should be induced. This may be followed by the oral administration of a pint of 1% solution of sodium thiosulfate if the patient is conscious, to be repeated in 15 minutes.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health*, 14:187, 1956.
2. American Cyanamid Company: Toxicology of Acrylonitrile, 1954.
3. American Petroleum Institute: API Toxicological Review, Acrylonitrile, 1948.
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5. BRIEGER, H., *et al*: *AMA Arch. Ind. Hyg. & Occup. Med.*, 6:128, 1952.
6. CHEN, K. K., *et al*: *J. Indiana State Med. Assn.*, 37:344, 1944.
7. DUDLEY, H. C., *et al*: *J. Ind. Hyg. & Tox.*, 24:255, 1942.
8. GISCLARD, J. B. (American Cyanamid Company): Personal communication.
9. Manufacturing Chemists' Association, Inc.: Safety Data Sheet SD-31-Acrylonitrile, 1949.
10. WILSON, R. H., and MCCORMICK, W. E.: *Ind. Med.*, 18:243, 1949.
11. WOLFSIE, J. H.: *AMA Arch. Ind. Hyg. & Occup. Med.*, 4:417, 1951.

METHYL ETHYL KETONE (Butanone)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 250 parts of vapor per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation*: Human experience plus animal studies.

B. SEVERITY OF HAZARDS:

(1) *Health*: Low, for both acute and chronic exposures. Capable of causing narcotic symptoms in man and animals, but irritant properties of vapor limit the possibility of voluntary exposure to high concentrations. No confirmed reports of serious chronic effects below irritating levels. It may cause drying and irritation of the skin.

(2) *Fire*: High. Flash point is -5.6°C (22°F) (open cup). Explosive limits are 1.8-11.5% by volume.[5]

C. SHORT EXPOSURE TOLERANCE: Limited by irritant properties of vapor; 30,000 ppm is intolerable to man because of irritation of eyes and nasal passages; 3000 ppm is intolerable for more than just a short period of time.[4,6]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown, but probably 10,000 ppm or above.

II. Significant Properties

It is a colorless liquid with a characteristic ketonic odor. Although the product now available usually has a high degree of purity, the following properties will be some-

what modified for the commercial grade:

Chemical formula:	$CH_3COCH_2CH_3$
Molecular weight:	72.10
Specific gravity:	0.805 (20°/4°C)
Boiling point:	79.6°C
Relative vapor density:	2.49 (air = 1)
Vapor pressure:	90.7 mm Hg, at 25°C
At 25°C and 760 mm Hg, 1 mg/liter of vapor:	340 ppm
1 ppm of vapor:	0.00294 mg/liter
Solubility:	Moderately, in water; forms azetropic mixture with water (boiling point 73.5°-C), at 89% by weight methyl ethyl ketone

III. Industrial Hygiene Practice

A. RECOGNITION: It has been widely used as a solvent for resins and lacquers, in paint removers, and in miscellaneous organic syntheses. It can be recognized by its characteristic odor (somewhat similar to acetone, but slightly more irritating).

B. EVALUATION OF EXPOSURES: Can be determined by methods similar to those used for other ketones. It can also be determined by mass spectrometry and by suitably calibrated explosimeter type instruments.[2,3]

C. RECOMMENDED CONTROL PROCEDURES: Any operations involving spraying should be conducted in a properly designed spray booth. It should be used only in the presence of spark proof equipment and with due care, to avoid exposure to any other sources of ignition. Occasional short exposures to small quantities can usually be controlled by good general ventilation. If irritating levels are encountered, this can be controlled by the use of personal respiratory protective equipment.

IV. Specific Procedures

A. FIRST AID: Remove any contaminated clothing promptly and flush skin with copious amounts of water. In case of eye burns, flush with water for 10 minutes.

B. PROPHYLACTIC PROCEDURES: Attempt to maintain work room atmospheres below 250 ppm.

C. SPECIAL MEDICAL PROCEDURES: None generally necessary. If trapped in an area of high concentrations, causing narcotic symptoms, remove individual to fresh air and treat symptomatically.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health*, 14:186, 1956.

2. ELKINS, H. B.: The Chemistry of Industrial Toxicology, p. 323. John B. Wiley and Sons, Inc., New York, 1950.

3. FAIRHALL, L. T.: Industrial Toxicology, p. 235. The Williams and Wilkins Co., Baltimore, 1949.

4. LA BALLE, M. S., and BRIEGER, H.: *AMA Arch. Ind. Health*, 12:623, 1955.

5. MARSDEN, C.: Solvents and Allied Substances Manual. Elsevier Press, Houston, Tex., p. 4.

6. PATTY, F. A., SCHRENK, H. H., and YANT, W. P.: Public Health Reports, 50:1217-1228, 1935.

ACETIC ACID

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 10 parts of vapor per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation*: Sensory response.[2]

B. SEVERITY OF HAZARDS:

(1) *Health*: Moderate, for acute; low, for chronic exposures. Effects are primarily irritation of eyes and mucous membranes. Solutions may cause severe skin or eye burns.

(2) *Fire*: Moderate. The lower limit of flammability is 4% in air. Flash point is 40°C (104°F) (closed cup).[4] Explosive atmospheres are unlikely except at elevated temperatures, because of low volatility.

C. SHORT EXPOSURE TOLERANCE: 200-500 ppm is extremely irritating, but may be borne for brief periods by some individuals.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown. Enforced exposure to hot vapor or hot liquid spray may cause edema of lungs.

II. Significant Properties

A colorless liquid, with a pungent odor.

Chemical formula:	CH_3COOH
Molecular weight:	60.05
Specific gravity:	1.049

Boiling point:	118.1°C.
Relative vapor density:	2.07 (air = 1)
Solubility:	In all proportions in water, alcohol and ether. Insoluble in carbon disulfide
At 25°C and 760 mm Hg,	
1 ppm of vapor:	0.00245 mg/liter
1 mg/liter:	407.65 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: By its odor and irritant effects.

B. EVALUATION OF EXPOSURES:

(1) *Chemical*: Collection in an all-glass device containing a 1:1 mixture of glycerol and water and Fleisher methyl purple.[3] Calibration of reagent gives measure of total acid in air.

C. RECOMMENDED CONTROL PROCEDURES: Enclosure of processes, accompanied, where necessary, with process and/or general ventilation, will maintain acetic acid concentrations below the irritant level.

IV. Specific Procedures

A. FIRST AID: Remove from exposure. Immediately flush skin or eyes with copius amounts of water. In the case of eye burns, secure medical attention.

B. BIOCHEMICAL ASSAY: None.

C. SPECIFIC MEDICAL PROCEDURES: In the event of inhalation of hot vapor or aerosol, the patient should be placed at bed rest and watched for involvement of lungs.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health*, 14:187, 1956.
2. COOK, W. A.: *Ind. Med.*, 14:936, 1945.
3. MILLER, F., *et al*: *AIHA Quart.*, 17:221-4, 1956.
4. National Fire Protection Association: National Fire Codes Vol. 1, p. 464.

Because of space limitations, it is impossible to list all methods of exposure evaluation. The selections have been made on the basis of current usage, reliability, and applicability to the usual industrial type of exposure. Any specific evaluation and/or control problem will involve professional judgment. This can best be done by professional industrial hygiene personnel.

Respiratory protective devices are commercially available. Their use, however, should be confined to emergency or intermittent exposures and not relied upon as primary means of hazard control.

A relative scale is used for rating the severity of hazards: nil, low, moderate, high, and extra hazardous.

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Hygienic Guides and Binders Available

INDIVIDUAL Hygienic Guides in loose-leaf form may be obtained from the American Industrial Hygiene Association, 14125 Prevost, Detroit 27, Michigan, at 25c each. Discount of 20% allowed on orders of five or more; 40% on orders of 100 or more. Also available are flexible loose-leaf binders for the individual Hygienic Guide sheets. The binders have been especially designed to provide maximum protection and ease of handling of the Guides. They will be particularly useful in keeping a permanent file. The binders are blue in color, with white lettering, and are fitted with ¾" rings. The price is $1.25. The Guides and the binders may be ordered on the blank on page 90.

✦ Selected Titles and Abstracts

—FROM FOREIGN EXCHANGE JOURNALS

THE FOLLOWING is a partial list of articles, by titles and authors, from journals received by the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION since the December, 1956 issue of the QUARTERLY in exchange for copies of the QUARTERLY.

Additional information on any of the journals or articles may be obtained from: CARROL S. WEIL, Senior Industrial Fellow, Mellon Institute of Industrial Research, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

I. ARHIV ZA HIGIJENU RADA I TOXSIKOLOGIJU (Yugoslavia). Vol. 7, No. 1 (1956).

Beginning with this issue the title of the above journal has been changed from the "Archives of Industrial Hygiene" to the "Archives of Industrial Hygiene and Toxicology." Papers on toxicological problems of a much wider range are now included.

Acute Occupational Poisoning by Nitrous Fumes. I. Beretic and I. Mohacek, pp. 31 to 40.

Acute Poisoning due to Trichloroethylene Ingestion. M. Fleischhacker, D. Djuric and I. Zadro, pp. 41 to 43.

A Fatal Case of Oral Intoxication by Mustard Gas. B. Volaric, pp. 45 to 49.

Trichloroethylene Poisoning. M. Fleishhacker and D. Duric, pp. 51 to 60.

The authors discuss the modern concepts regarding pathology and clinical aspects of trichloroethylene poisoning. Results are given of recent investigations of the metabolism and secretion of metabolites, especially of trichloroacetic acid.

II. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 32, No. 6 (1956).

The Distribution of Radioactive Lead (Thorium B) in Blood of Cattle. Hachiro Nishizono, pp. 434 to 439.

On the Industrial Poisoning in the Plastic Factory. Kikuo Fujiwara and Hiroshi Nakayama, pp. 440 to 444.

Studies were performed on the toxicity of stabilizer, dibutyl tin dilaurate, on workers and on animals. Workers had signs of irritation in the upper respiratory tract. Urobilin and urobilinogen were detected in the urine and changes, suggesting possible anemia, occurred in the haemogram. Five ppm for six hours was toxic to adult rats; the "minimum toxic concentration" (acute?) was 0.5 ppm. Temperatures above 30°C accelerated poisoning. Young animals were more susceptible than adults.

On the Circulation Time of the Silicotics, Especially about the Comparison between the Lobelin Time and the Ether Time. Yoshihiko Matsushita, pp. 479 to 483.

III. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 32, No. 7 (1956).

Experimental Studies on the Chronic CS_2 Poisoning in Rabbits (Part I.) The Study of Liver Functions of CS_2 Poisoned Rabbits. Yoshinori Masuda, pp. 521 to 533.

Rabbits were exposed to 200 ppm CS_2, six hours a day, six days a week for five months. No body weight, appetite or general behavior changes occurred for four months.

Paralysis of the hind legs was seen thereafter. Decrease of albumin-globulin ratio was found in 40 days of exposure. Glycogen synthesizing power of the liver was apparently disturbed in 70 experimental days. Oxygen consumption of liver slices were remarkably decreased when compared with controls. Galactose tolerance test was positive, serum cholinesterase not changed, hepatosulphalein test and thymol turbidity test were negative.

Effects of Glucoronic Acid and Methionine on Donaggio Reaction, Urobilinogen Discharge Amount and Flicker Value of Heavy Muscular Workers Subject to High Temperature During Summer Months. Seisuke Satoh, pp. 555 to 564.

On the Radioactive Contamination and Its Removal. The Contamination of Textile and its Removal. Norio Ishida, pp. 565 to 575.

The Three Cardinal Forms of X-Ray Findings in Silicosis (Report IV-Silicosis Forms in Relation to Respiratory Function). Harunori Asakawa, pp. 576 to 563.

◆ President's Page



BY THIS TIME all of our members will have had the opportunity to look over the preliminary program for the St. Louis Industrial Health Conference. The rapid rise in the number of technical papers offered on the AIHA program is so phenomenal that our Annual Meeting has become the mecca for those who must keep abreast of developments in industrial hygiene.

A wide spectrum of papers will be presented at the general sessions. Two themes, though, have been especially developed. The first one concerns the health aspects of radiation, while the second deals with the age-long problem of respiratory protection in light of the more toxic materials now encountered. In addition to the general sessions, some 80 papers will be presented at the concurrent technical sessions. Bound abstracts will be available to help dispel the dilemma of being able to attend only a fraction of the presentations of interest.

The program as outlined above, with the technical committee meetings and the annual banquet, promise to make this conference one of the best—not only from the standpoint of gaining first-hand acquaintance with the latest technical developments in the field, but also of meeting old friends and sharing experiences. A special program is being prepared for the ladies, so don't forget to bring along the spouse.

See you at the Kiel Auditorium.

Lester V. Cralley

✦ Annual Meeting

THE EIGHTEENTH Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION will be held April 22-26 at Kiel Auditorium, St. Louis, Missouri. Four other organizations, the Industrial Medical Association, the American Conference of Governmental Industrial Hygienists, the American Association of Industrial Nurses, and the American Association of Industrial Dentists meet during the same week and join with AIHA in the 1957 National Industrial Health Conference.

The preliminary program lists 99 papers to be given at the AIHA sessions and the joint sessions in which AIHA participates. Concurrent sessions will again be held in the fields of air pollution, engineering, toxicology, chemical and analytical, radiation, and noise. Toxicology leads in the number of papers to be presented with 26, followed by radiation with 19. The remainder of the fields of interest have the following numbers of papers: air pollution, eight; engineering, seven; joint air pollution and engineering, eight; noise, five; chemical and analytical, eight.

A general session of AIHA will be devoted to the problems of respiratory protection. Five papers will be offered at this session. The opening session will be held jointly with the American Conference of Governmental Industrial Hygienists and will be devoted to radiation and radiation hazards.

Highlighting the meeting will be the Annual Banquet on Wednesday evening April 24 followed by the Donald E. Cummings Memorial Lecture. This year's lecturer is H. H. SCHRENCK, Ph.D. of the Industrial Hygiene Foundation, Pittsburgh.

DR. SCHRENK joins a distinguished group who have been recipients of the Donald E. Cummings Memorial Award:

Henry Field Smyth, Jr., Ph.D.	1956
James H. Sterner, M.D.	1955
Frank A. Patty	1954
Warren A. Cook	1953
Leonard Greenburg, M.D.	1952
Theodore F. Hatch	1951
Philip Drinker, Sc.D.	1950
Alice Hamilton, M.D.	1948
William P. Yant, Sc.D.	1947
Leroy Gardner, M.D.	1944

The lecture will be published in a future issue of the *AIHA Quarterly*.

✦ News of the Local Sections

Northern California

THE LEGAL Committee of the Northern California Section, composed of CHRISTINE EINERT, M.D., Chairman, LAWRENCE SCHMELZER and GEORGE TAYLOR, has submitted an Interim Report concerning accreditation of industrial hygiene personnel. Their recommendations are: (1) that accreditation is the most appropriate method of ensuring to the public the opportunity to obtain competent industrial hygiene laboratory work; (2) that the Northern California Section of AIHA preferably in conjunction with the Southern California Section pursue an active program of accreditation; (3) that the present committee with whatever additional members are desired, continue to work out appropriate standards, criteria and methods for accreditation.

At a meeting of the Section on November 27, CAPTAIN A. R. BEHNKE, MC, U.S.N. spoke on "The Workman in the Stress Environment," in which he explained how naval operations present many problems in unusual stresses due to work under compressed air or in reduced pressure in high altitude flying. CHRIS EINERT and PAUL CAPLAN discussed a joint West Coast meeting of several groups to be held in Los Angeles next October 4, to be called "Western Industrial Health Conference."

NELSON B. GARDEN, Chief, Health Chemistry Section, Radiation Laboratory, University of California, Berkeley, was speaker

at the January 22 meeting. He discussed problems in human exposure arising from the increasing use of radioactive materials.

Southern California

AT THE meeting of the Southern California Section on January 10, CAPTAIN A. R. BEHNKE, MC, U.S.N., Radiological Medical Director, U. S. Naval Radiological Defense Laboratory, San Francisco, spoke on "Physiological Effects of Environmental Stresses."

Philadelphia

THE ATTENDANCE of the November meeting of the Philadelphia Section suffered somewhat from the competition of the Industrial Hygiene Foundation meeting in Pittsburgh and the annual American Public Health Association meeting in Atlantic City. However, the 28 members who were able to attend heard an interesting discussion by JOHN SKINNER, Industrial Hygienist of the American Mutual Liability Insurance Company, who described the wide range of interests and functions of industrial hygienists in the insurance industry, covering such areas as workers' occupational health, contaminated and adulterated products, and pollution of atmosphere and streams.

The Tri-Section meeting in Trenton on December 7, was well attended, interesting and informative. Two papers presented were "An Experimental Study of Dust Deposition in Human Subjects," by PAUL E. MORROW, Ph.D., Assistant Professor of Pharmacology, University of Rochester, and "Industrial Applications of Nuclear Energy," by A. J. STEVENS, Ph.D., Manager, Nuclear Energy Division, Budd Company. LES CRALLEY was the dinner speaker, reviewing the past and present of AIHA and outlining the ambitious plans for its future.

The Annual Philadelphia Fire and Safety Conference is scheduled for March 13 and 14th, 1957, at the Bellevue Stratford Hotel, Philadelphia. The Philadelphia Section is sponsoring a morning session March 13. The subject is "Health Problems Involved in the Sale and Use of Toxic Materials," which will be a discussion from prepared questions and will be slanted toward the effects of the "labelling laws" and the standards of the Manufacturing Chemists Association on the sale and use of toxic chemicals. The experts are: DR. L. C. MCGEE, Medical Director, Hercules Powder Company; DR. JOHN ZAPP, Toxicologist, Haskell Laboratories, Du Pont Company; HARRIS GREEN, Attorney-at-Law, Rohm & Haas Company; and WILLIAM E. SHOEMAKER, Assistant Division Engineering Manager, American Mutual Liability Insurance Company.

PERSONAL NOTES: AL BRANDT has been in South America conducting industrial hygiene studies at Bethlehem Steel Company's operations in that area . . . . TOM BULLARD has been appointed Safety Director of the Budd Company.

Northeastern Ohio

THE SECOND meeting of the reactivated Northeast Ohio Chapter was held November 30, at the Ferro Corporation plant in Cleveland with 20 members and guests attending. Lunch was followed by a trip through the manufacturing and laboratory facilities of the plant. The group then met in the Conference Room for a question and answer period presided over by DR. W. MARKLEY, plant physician. Points under discussion were—materials handling, ventilation, personal hygiene, housekeeping, respirators, physical examinations, blood and urine lead tests, developing and maintaining cooperative employee attitudes.

The following officers were elected for 1957: Chairman—I. MATELSKY, Industrial Hygienist, Lamp Division, General Electric Company, Nela Park, Cleveland; Vice-Chairman—A. L. GREGORIC, Industrial Hygienist, Diamond Alkali Company, Painesville, Ohio; and Secretary-Treasurer—H. CUTTER, Industrial Hygienist, City of Cleveland.

On February 26, the meeting of the Northeastern Ohio Section was held at the Lighting Institute of the General Electric Company, Nela Park. In addition to a tour of the Institute, the program included a discussion and demonstration of the "How and Why of Good Lighting." Of particular interest was the discussion of problems encountered in industrial lighting.

Chicago

AIHA and ASSE held a joint social meeting December 5, with 134 persons attending. The work of the Program Committee made the event such a success that there is a possibility that it will become an annual affair.

The Council on Industrial Health of AMA provided the program at the meeting in January. Co-sponsors of this meeting with the Chicago Section were the Industrial Medical Association and the Medical Directors Club of Chicago. E. S. JONES, M.D., President, Industrial Medical Association, was Program Chairman. Speakers were B. DIXON HOLLAND, M.D., Secretary; MARJORIE W. GRIGSBY, MURRAY KLUTCH and CLARK D. BRIDGES, all of the Council on Industrial Health. They discussed the organization and purposes of this top level group in organized medicine. LESTER V. CRALLEY, Ph.D., A.I.H.A. national president, was the speaker at the February meeting. DR. CRALLEY spoke on the status of AIHA and outlined future plans for this expanding organization.

Gulf Coast

AT A DINNER meeting of the Gulf Coast Section held December 3, the subject for discussion was "Texas Regulations on Radiation Exposure." There was a panel discussion provided by the following: J. W. HAMMOND, Humble Oil & Refining Co., Moderator; DR. WARREN SINCLAIR, M.D., Anderson Hospital; LEONARD F. TISCHLER, Tracerlab, Inc.; MARTIN WUKASCH, Texas State Department of Health. Items handled by the panel were (1) need for protection; (2) present regulations; (3) field application of regulations; (4) facilities available to help achieve compliance; and (5) questions and answers.

✦ *Obituary*

OLIVER G. STAM, 56, died January 12, 1957, at his home in Cedar Grove, New Jersey, after a long illness. He worked many years as an industrial hygienist in New York before he became ill. He was last associated with Union Carbide and Carbon Corporation.

MR. STAM was born in Jonkoping, Sweden and came to the United States in 1911. He was a member of the New Jersey Section of the American Industrial Hygiene Association.

Civil Service Positions for Industrial Hygienists

THE UNITED STATES Civil Service Commission announces that an examination is now open for Industrial Hygienist (Health Physicist) for filling positions principally at the Navy Radiological Defense Laboratory, San Francisco, California. The salaries range from $4,525 to $7,570 a year. To qualify, an applicant must have a degree from an accredited college, or an equivalent four years of technical experience, in physics, chemistry, biology, or engineering. In addition, he must have had professional experience in the fields mentioned including experience in health physics. No written test is required. Further information and application forms may be obtained from the U. S. Civil Service Commission, Washington 25, D. C., or from the Board of U. S. Civil Service Examiners for Scientists and Engineers, Navy Department, 1030 East Green St., Pasadena 1, California. Interested persons should ask for Announcement No. 12-14-6 (56).